2015-09-30

Evaluating the Usability of the Laboratory Information System (LIS) in Coombe Hospital and Hail Hospital

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A dissertation submitted in partial fulfilment of the requirements of
Dublin Institute of Technology for the degree of
M.Sc. in Computing (Knowledge Management)

September 2015

I certify that this dissertation which I now submit for examination for the award of MSc in Computing (Knowledge Management), is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the test of my work.

This dissertation was prepared according to the regulations for postgraduate study of the Dublin Institute of Technology and has not been submitted in whole or part for an award in any other Institute or University.

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Signed: ________________________________

Date: ***04 September 2015***

ABSTRACT

Today, with the rapid evolution of technology, there has also been a rapid development of medical software and systems in hospitals. These systems and software are now being used globally in many hospitals by users of different languages and cultures. Governments and private hospitals pay large sums of money to utilise highly efficient technology. When systems are changed or updated, employees often find it difficult to deal with the characteristics of the new systems. Also, behavioral factors, such as the fear of committing simple errors, might affect system performance and prevent the full utilization of the staff potential.

In this research we will measure the usability of the Laboratory Information System (LIS) in two different countries, the Coombe Hospital in Dublin, Ireland and the Hail Hospital in Hail, Saudi Arabia. Two of the most accepted usability models – SUS and QUIS - are used in this research. The comparison of the two hospitals results displayed common weaknesses/strengths as well as differences between two health institutions situated in countries that differ in language and culture. Questionnaires were distributed to both hospitals and interviews were conducted with the employees of each hospital to discuss some of the points about the system.

After the analysis of questionnaires and interviews, the search results determined the common system problems for both hospitals. Consequently system problems from the analysis of both surveys were made available to each hospital to achieve greater efficiency of the system.

Key words: Coombe Hospital, Hail Hospital, laboratory Information System, knowledge management in health sector, knowledge management, usability, SUS, QUIS.

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to my parents, for all their help and advice, and continued support toward the end of the Master Degree.

Areej I applaud you profusely for your continued, friendship, patience and assistance.

My supervisor Pierpaolo Dondio has been a fount of knowledge and enthusiasm which were hugely beneficial during this research. For this I would like to extend my gratitude.

To all those who took part in the pilot, surveys and interviews which contributed to this work, I greatly appreciate you for your co-operation and engagement.

In remembrance of the victims of the Syrian conflict particularly the children who inspired me to prevail with this dissertation.

Finally, to my family and friends your support was invaluable to me.

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1 INTRODUCTION

1.1 Overview of Project Area

The aim of this thesis is to evaluate the usability of LIS (laboratory Information System) a popular healthcare knowledge management software. It is therefore relevant to start this thesis by introducing the concept of knowledge management and the research area pertinent to this work.

There is no universal definition of knowledge management but many experts have agreed on one particular single definition. Uriarte states that: "*knowledge management is the conversion of tacit knowledge into explicit knowledge and sharing it within the organisation. Putting it more technically and accurately, knowledge management is the process through which organisations generate value from their intellectual and knowledge based assets. Defined in this manner, it becomes apparent that knowledge management is concerned with the process of identifying, acquiring, distributing and maintaining knowledge that is essential to the organisation*".

Uriarte divided the concept of knowledge management to three parts:

- The results-oriented definition: To have the right knowledge at the right place, at the right time in the right format.
- The process-oriented definition: The systematic management of process by which knowledge is identified, created, gathered, shared and applied.
- The technology oriented definition: Business intelligence + collaboration + search engines + intelligent agents.

In the domain of healthcare, knowledge to be managed assumes specific characteristics, Three types of healthcare knowledge can be identified:

- Provider knowledge: this is a provider of knowledge for people working inside the hospital and can be either a person or a device. One of the best examples of a provider is a doctor who gives guidance to those working in the hospital through their experience. Many people believe that the most important knowledge that is given by doctors is tacit knowledge. This is because a doctor is conducting expert work for many years and has experience in dealing with patients, treatments and disease prevention.

- Patient Knowledge: Symptoms that affect the patient during the disease are to be discovered and made known only to them. This knowledge will help doctors and specialists to identify the disease and give treatment. Also when recorded, studied and identified, this information facilitates the identification of the disease in other patients.
- Organisational Knowledge: Resources are made up of many kinds of knowledge which can be accessed by both patients and doctors. Doctors can enquire and get references to help diagnose disease. Furthermore, patients can access a lot of information about illnesses and advice on how to deal with them (Chen 2012).

Healthcare Knowledge Management (HKM) can be characterised as the systematic creation, modelling, sharing, operating and translating of healthcare knowledge to improve the quality of patient care. The main objective of the application of the knowledge management system is to improve the performance of staff, control the time, decision-making, take advantage of those with previous experience through useful techniques, improve performance and accelerate workflow. A lot of organisations and hospitals are quick to apply the latest techniques of knowledge management (Raza, S. 2012).

There are a lot of systems that work on knowledge management in healthcare companies and hospitals. These systems enhance the performance of the staff, for the transfer of tacit knowledge and to support decision-making to take the appropriate treatments for patients. Also, healthcare professionals benefit from the experience by writing comments and sharing knowledge through these systems.

Recently, many companies around the world have started to participate in the manufacture and development of knowledge management systems in hospitals, such as patient-data records systems, pharmacies and laboratory systems. These regulations are tested by researchers and developers in some aspects, such as usability, reliability, and quality.

This research focuses on the use of two models to test Usability of the Laboratory Information System (LIS). This paper assesses how both models are used in two different hospitals: the Coombe Women and Infants' University Hospital in Dublin and the Hail Hospital in Saudi Arabia. The comparison between the hospitals is being conducted to see if the LIS system achieves usability and to suggest recommend actions to the stakeholders to improve and further develop the system.

1.2 Project Background

Hunt (2003) defines knowledge as a characteristic found in people who are highly experienced and cannot be directly observable. Many people and organisations have become aware of the importance of knowledge these days and have invested into creating benefits for the company. Knowledge management is the conversion of tacit knowledge into explicit knowledge and sharing it within an organisation. It is a process that companies are using more technically and accurately. Today many companies encourage employees to share knowledge to raise the performance of staff (Uriarte, 2008).

When users are struggling with the obstacles and complexities of a particular system, system stakeholders resort to Usability Testing to improve the system's performance. The good application of Usability Testing helps developers and users to improve the collection of the right data and their analysis, in order to reveal the errors and gaps in the system usability. This method helps users and developers to make decisions that facilitate and improve the system's performance (TechSmith, 2015).

The present work will test the usability of the healthcare knowledge management system LIS using the QUIS and SUS usability tests.

Adam (2007) describes LIS as a "*suite of software applications that helps to manage the daily operations / workflow of a laboratory. Accounted for as one of the largest sources capital expenditure in any diagnostic laboratory, a successful LIS implementation not only ensures effective control and management of resources but also offers the following benefits: Increase in productivity, Greater data accuracy and Reporting and Statistics*".

The Questionnaire for User Interaction Satisfaction (QUIS) is a usability testing tool which has been designed to gauge computer users' subjective satisfaction with the computer interface. The QUIS contains a demographic questionnaire, an overall measure of satisfaction, and measures of user satisfaction in four specific interface aspects (screen factors, terminology and system feedback, learning factors, and system capabilities). The QUIS was designed to assess users' subjective satisfaction with specific aspects of the human/computer interface.

Among many models that measure the user interface, the System Usability Scale (SUS) has gained recognition as one of the most effective for several reasons. Firstly, it consists of 10 questions which are easy and understandable. Secondly, once the researcher has collected the results, it is easy to analyse and give clear results. Thirdly, it can be used on many systems such as websites, cell phones, interactive voice response (IVR) systems (both touch-tone and speech), TV applications, and more (Bangor, A., Kortum, P. and Miller, J. 2009).

1.3 Description of the Dissertation

The significance of investigating the root problems within the LIS system cannot be overstressed. The research will identify the usability problems by the staff in the laboratory. After that, these problems will be delivered to the IT department in both hospitals so that they will be eradicated thus achieving a more efficient system and comfortable method of dealing with the LIS system. Overcoming these minor mistakes in the LIS system assists employees in becoming more productive, obtaining more accurate results and taking advantage of all the system properties.

There are a lot of systems and techniques to share knowledge in hospitals. These systems, traditional or technological, help every category of staff to share their knowledge easily. Hospital systems are large, complex and developing rapidly. Therefore, hospital systems are subject to changes and most users find it difficult to deal with the new features with a consequent loss of performance. In addition, the situation is complicated by the presence of many different types of system users: doctors, nurses, interns, people with disabilities, the elderly and the ordinary staff.

Systems such as LIS should serve all kinds of people. Disabled users might find it difficult to deal with colours, font size, and some pictures. The system does not support trainees needing additional information about the characteristics of the system, users may find it difficult to understand some of the messages from the system and they are not receiving much assistance from employers.

Healthcare data is critical: errors occur in inputs, (for example the names of patients and treatments) may have serious consequences and they can only be minimized by a carefully designed usable system. The level of usability of the system is therefore central to the high-performance of the staff. Hospital systems must be accurate and avoid mistakes. Therefore, it is important to evaluate the usability to identify system problems.

This research will test the effective usability scale and usability satisfaction of the Laboratory Information System (LIS) in two different hospitals in Ireland and Saudi Arabia. Examination will occur through two of the most popular tools to assess systems usability, namely QUIS and SUS, which have proven quality in previous research. This research will also identify the role of LIS in the exchange of knowledge works in hospital as it is perceived by staff.

Previous research has been conducted in this area, specifically in the application of knowledge management techniques and methods of knowledge sharing in hospitals. This research has assisted systems to enhance performance and reduce errors and the present study aims to contribute in a similar manner.

1.4 Research Methodology

The methodologies to be used are qualitative and quantitative so as to ensure the accuracy of search results. For qualitative methodology, there are many models to test the usability of a system. In this research, two models will be used which suit the LIS situation.

- System Usability Scale (SUS): This is a quick and reliable tool to measure the Effectiveness, Efficiency and Satisfaction of usability.

- Questionnaire for User Interface Satisfaction (QUIS): The questionnaire for user interface satisfaction (QUIS) takes users' views and evaluates user acceptance of a computer interface

Both models will be explained in more detail in the usability and experiment chapters.

Regarding the qualitative methodology, a semi-structured interview will be used to obtain the views of people who use the system. The interviews will be with the people who use the LIS system namely doctors, nurses, staff and trainees. The goal of the interviews is to get more accurate information from the users of the system.

1.5 Research Aim and Objectives

1. Perform a comparative evaluation of the usability of the LIS system in an Irish and in a Saudi hospital using the QUIS and SUS methodology. The goal is to quantify the level of usability of the system and understand if the system is able to deal with a wide variety of users smoothly and with flexibility. This research aims to identify some of the challenges faced by users and the solutions that can be developed to overcome them.

2. Produce a set of Recommendations for Hospital managers. Based on research findings, a list of solutions will be proposed in order to make the system more effective. At the end of the research and after the application of the tests and the discovery of system problems, the hospital will be given a list of recommendations

3. Measuring user satisfaction. This research is an opportunity that will allow participants to express their opinions and assess the problems within the system accurately. Through interviews and questionnaires it can be determined what the extent of employee satisfaction is about the system. Also, it will be possible to list the staff's requirements which can be applied to help raise the performance.

1.6 Scope and Limitations

In this research, the challenge is that the system used by doctors, staff and trainees will be large and complex. It may be difficult to measure usability in all respects. Two models will be used to help in finding solutions to the problems of the system in both hospitals.

In addition, the work environment in hospitals is always busy. Employees do not have enough time for an interview so many details about the system will be answered quickly in the survey. Also, the Privacy Policy in hospitals is an issue and staff may fear giving more information about the system.

1.7 Document Outline

Chapter 1 : an introduction of the dissertation

Chapter 2: This chapter will offer a general definition of the kinds of knowledge and then knowledge management goals. Also, it will discuss management and the sharing of knowledge in hospitals and how these can be applied.

Chapter 3: This chapter will offer a definition of usability, outlining the objectives and the most important models to measure usability. Also, the global institutions that evaluate usability on systems will be discussed.

Chapter 4: This chapter will describe the LIS system, including methods of use, objectives and data processing.

Chapters 5 and 6: This will outline the experiment design (5) and the discussion of the results (6). Chapter 6 will also explain ways to implement models in both hospitals. This chapter will also discuss the results and methods of analysis and the result comparison to each hospital.

Chapter 7: This will offer a conclusion and give a list of weak points through which developers can improve the system.

2 LITERATURE REVIEW

2.1 Introduction

In this chapter, all stages of the knowledge management lifecycle will be explained in general and we will focus on the stage of knowledge sharing. After that, knowledge management in health sector especially will be defined in more detail as well as perspectives for the use of KM in health care that is needed when applying KM in hospitals. In addition, a definition of knowledge sharing will be provided that is suitable for healthcare. Finally, there will be a description of knowledge sharing in hospitals both via technology and face to face.

2.2 Knowledge Management

2.2.1 Knowledge

(Uriarte, 2008) "*Knowledge is defined as the remembering of previously learned material. This may involve the recall of a wide range of material, from specific facts to complete theories, but all that is required is the bringing to mind of the appropriate information. Knowledge represents the lowest level of learning outcomes in the cognitive domain*".

There are two categories of knowledge:

1- Explicit knowledge: this knowledge is formalized, modified and codified as well as easy to retrieve, identify , and store in text, documents and media. This type of knowledge is the most easily handled and effective at facilitating the user. People have access to the precise information they require, they can to update, increase, and delete information. It enables successful partnerships between people. Within systems where explicit knowledge is available there are the following aspects :
    - Explanation: the knowledge provider can describe the information properly.

- Awareness: The members should be aware that knowledge is accessible.
- Access: the knowledge members can reach the knowledge provider.
- Guidance: The knowledge provider must specify the type of knowledge that can be accessed, the recipient should not be given a lot of knowledge in a short time and it should be accessible.

2- Tacit knowledge: It is knowledge that's difficult to write down, visualize or transfer from one person to another. It is a major challenge for knowledge management in many areas of science, health and other. The reason is that it is difficult to detect as a lot of knowledge is hidden and not exploited in the right way. For example, Innovation is difficult to be taught and written. There's no process or training that can be guaranteed to make you an inventor. Innovation extends from experience (Perkins and Bennett, 2012).

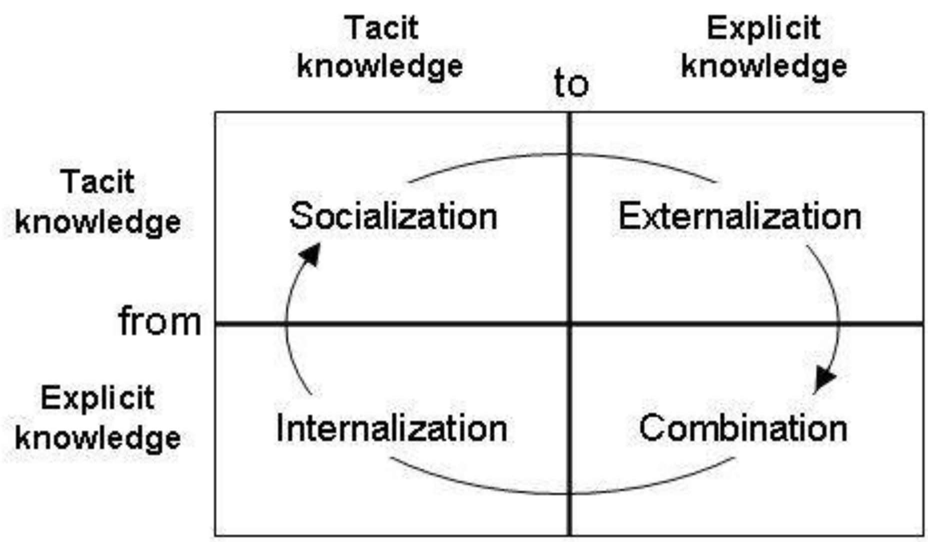

Figure 1 Type of Knowledge . (Hcklab.org, 2015)

2.2.2 Knowledge Management Definition

David Gurteen (1999), states that in the past people used to believe that knowledge was power and had to be maintained by an expert. However, he claims that there is little benefit in keeping knowledge secret. He states that knowledge must be activated and utilized. The exchange of knowledge has many benefits, including the development of job performance, personal development, the ability to solve problems and to meet people with common interests. There are a lot of factors that contribute to the promotion of sharing knowledge.

There is no universal definition of knowledge management, but many experts agree on definitions related to each other. Knowledge management is the conversion of tacit knowledge into explicit knowledge and sharing it within the organization. After conversion this is utilized across specific techniques, creating, sharing and applying needed by institutions and companies (Uriarte, 2008).

(Bhojaraju, 2005) defines KM as a discipline that promotes an integrated approach to identifying, managing and sharing all of an enterprise's information assets and defines KM as a discipline that promotes an integrated approach to identifying, managing and sharing all of an enterprise's information assets. Information can be databases, documents, procedures and the expertise of staff. Knowledge management also includes the enablement, implementation and maintenance of a good structure which allows for the exchange of improved knowledge within companies and institutions.

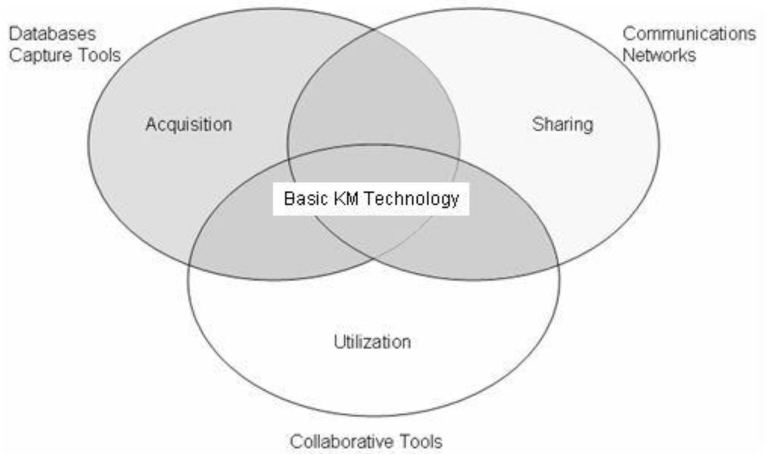

Figure 2 Knowledge Management (Hcklab.org, 2015)

2.3 The Knowledge Management Cycle (KMC) Model

The standard Knowledge Management Cycle (KMC) contains six phases: identify, store, share, use, learn, improve, and create. (Evans, Dalkir and Bidian, 2014)

Create : At this stage, the information is collected from different sources, people or devices such as electronic documents & notes in preparation for the next phase.

Use: After collecting the information or receiving it electronically the data is completed on demand for example, completion of sample examination procedures.

Enrich: Add the information and documents to give it a greater value. For example, add the results and reports of samples.

Share: Sharing knowledge with staff and departments within or outside the organization. For example, sending the results to the department or to another hospital.

Assess: assess future information and knowledge needs to fit the organisation’s strategy.

Build knowledge: The development of new knowledge over prior knowledge such as the discovery of the symptoms of a disease through results. (Dwbh.co, 2015)

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Figure 3 Knowledge Items

(Dwbh.co, 2015)

This paper will be focused on the stage of the data involved in the health sector, especially in laboratories and to achieve the main objective of this research, test usability of LIS system through which staff share knowledge. After explaining general concepts of knowledge and knowledge management the chapter will address knowledge management and knowledge sharing in the health sector. In the coming sections we will focus on knowledge management in the health sector and how to test the usability of KM solutions in the health sector.

2.4 Knowledge Management in Health Sector

(Abidi, 2008) gives a definition of HKM: "*Healthcare Knowledge Management (HKM) can be characterized as the systematic creation, modeling, sharing, operationalization and translation of healthcare knowledge to improve the quality of patient care. The goal of HKM is to promote and provide optimal, timely, effective and pragmatic healthcare knowledge to healthcare professionals (and even to patients and individuals) where and when they need it to help them make high quality, well-informed and cost-effective patient care decisions. In practice, HKM is pursuing this goal through the advancement of innovative knowledge-mediated solutions and their integration in institutional workflows, to improve the quality, efficiency and efficacy of healthcare delivery system knowledge sharing*"

A lot of health companies and hospitals begin to apply the latest knowledge management systems to their importance in the efficiency and quality of management. Hospitals in the management process are keen to involve staff, doctors, patients and management. There are a lot of systems and software that help knowledge management but the hospital's success in knowledge management depends on the efficiency and application of regulations. Hospitals must also be careful to apply the latest information systems and knowledge management for the following reasons:

- Minimizing the paperwork by introducing electronic health records for patients.
- Rapid retrieval as well as fast and reliable communication of electronic health records to distant places using modern information and communication technology.

- Decision-making based on an analysis of the patient's history and current data will increase overall efficiency even in remote areas.
- Reduction of health care costs by eliminating the repetition of tests by different doctors.
- Improvement in the quality of care by the lessening of medical errors due to inaccurate and untimely information (Mahmood *et al*., 2012).

In addition, when applying regulations they should take into account the privacy and security issues. As ICT use increases further in the health sector, some privacy and security issues will arise. Information will be available only to the patient and doctors but is shared with other organizations and hospitals, not just the results of the patients' samples, but the patients' personal information such as addresses, which has a different privacy law from one country to another. (Mahmood *et al*., 2012). Knowledge management systems support healthcare workers in using available knowledge to develop organizational learning. For example trainers in hospitals, if the hospital allowed community of practice they will learn and develop their skills faster. (Acharyulu, 2011).

2.5 Perspectives for the Use of KM in Health Care

Besides the current knowledge management applications in the health care sector, few perspectives present an opportunity to develop new health care KM applications. These perspectives are virtual communities, Electronic Health Record (E.H.R.), and public health. (El Morr and Subercaze, n.d.)

- Virtual communities: "Virtual" health care providers of different disciplines (e.g. medicine, nursing, social work, physical therapy, etc.) can create teams in which they combine their knowledge and expertise to provide a comprehensive plan of care. These teams are involved in patient care methods, treatments, symptoms of disease, and discussions about their experiences. Also, patients have tacit knowledge about their medical condition and the way they experience their conditions and this tacit knowledge constitutes a mine of information for clinical practice; indeed, it allows to get insight into the patient experience and hence assess her/his quality of life as well as the impact of a drug on a person’s life.

- Electronic Health Record (E.H.R.): many countries around the world try to apply an Electronic Health Record. In the developing countries, they build computerized health records to acquire the right information about a patient at the right time, and to use the E.H.R. data for diagnosis purposes, for personal health decision support, for public health decision support, and for research purposes as well. However there are difficulties in improving and developing HER efficiency. KM in the health sector plays a crucial role in assembling vital information about patients from knowledge shared by doctors and researchers. Also staff heads can improve their skills and management efficiency by sharing coordinated information with other team leaders. (El Morr and Subercaze, n.d.)
- Public health: if doctors, departments and researchers participate in their knowledge it will increase the level of awareness about diseases and the best way to treat them. KM in the health sector aids in regulation, making decisions, planning, developing strategies and facilitating the acquisition of knowledge tools. (El Morr and Subercaze, n.d.).

2.6 Knowledge Sharing

Knowledge sharing is an exchange (information, experiences and skills) among people in public places and among colleagues within companies. Many companies have found that encouraging employees to share knowledge helps to develop the performance of staff which in turn assist the company's development (Thampi, 2010).

For Aliakbar, Yusoff, and Moghaddam (2013), the definition of the exchange of knowledge is transferring the knowledge from one person to another person or several people within an organization. The exchange of knowledge makes a lot of expertise available to anyone within the virtual community which provides an opportunity for members to share previous experiences or new experiences.

Bond, Cave, and Ballantyne (2013) define the concept of knowledge sharing as broad and large which includes a lot of small concepts such as knowledge transfer, exchange, utilization, dissemination, sharing, brokering, mobilization, application and translation. It is important for the owners of companies to access these concepts and choose what suits them. Also, this research focused on the planning establishment of a technique to share knowledge by identifying the domain, time and the main objective of this technique.

2.7 Knowledge Sharing Strategies

There are plenty of models to apply knowledge sharing to. Each department in hospitals chooses models based on the culture and structure of the hospital. In general, there are three categories and each category has models: writing, speaking, and information technologies (Tsui et al., 2006).

Writing

Writing is the most important data sharing strategy in the health sector. Codification and writing research in one place helps to develop systems, even if the author moved to another location. Also, writing allows the researchers to amend and review articles before publication unlike other forms of recording, such as a meeting. Sharing knowledge in written form includes articles, books, chapters, media advisors and the use of newsletters. Each type of research has a specific rule that must be put in place when it is published. The research can be papers or electronic papers which are found in databases, with media advisors, and newsletters (Tsui et al., 2006).

Speaking

Knowledge-sharing strategies include conferences, lectures and presentations, workshops, conversation sessions, and meetings, traditional conferences and discussion with researchers who do not share common interests.

Information Technologies

If researchers and staff cannot meet each other due to distance they can exchange knowledge through technology and the Internet. Therefore, where possible, online experience-sharing strategies should be used to support existing information-sharing communities rather than be considered as stand-alone knowledge-sharing activities. Web pages are a link between experts and researchers through which they can contact each other. In addition, Discussion Forums are tools that facilitate sourcing knowledge and research where people may ask questions and suggest solutions. (Tsui *et al*., 2006)

2.8 Knowledge Sharing Motivations and Barriers

Aliakbar, Yusoff, and Moghaddam (2013), state that the definition of the exchange of knowledge is giving the knowledge from one person to another person or several people within an organization. The exchange of knowledge makes a lot of expertise available to anyone within the virtual community. This provides an opportunity for members to share previous experiences or discover new experiences. According to Hassandoust, (2011), the sharing of knowledge should be under one specific system within an organization or academic environment. This system should also have specific clear goals that aim to develop the people or the organization. However, Hassandoust claims that we need to search and find out influencing factors. These factors give a vision for the main motivations and barriers that prevent the individuals from participating in a virtual community.

Aliakbar, Yusoff and Moghaddam (2013), however, view it differently as the distribution of the knowledge between members inside an organization creates these communities. Knowledge sharing happens, they say, when individuals mutually exchange their tacit or explicit knowledge and commonly create new knowledge. In some cases, this knowledge contributes to the success of individuals and institutions across the world. It is this view of virtual communities that makes them most interesting to many disciplines.

Vuori and Okkonen (2012) conducted a study in one company where they asked the employees about what motivates them to share their knowledge with others. They then calculated the results to determine the greatest motivating factors. Overall, "*I want to help my organisation to reach its goals"* and *" I enjoy helping my colleagues* *by sharing my knowledge"* came out on top. From this, we can see that members often prefer working in a team rather than working alone. The second highest standard answers were *"I feel that I have something to give"," I want to achieve my own goals"* and *"Expanding my scope of association".* In this point, members share their knowledge for their personal goals. In third place were *"I believe it secures my job"," Gaining financial rewards" and "It may bring me promotion opportunities".* It can be clearly seen that the members work towards achieving personal desires. These indicators are clear and suggest that the exchange of information within an organisation leads to a sense of helping the work community as a whole rather than working simply to gain personal goals (Vuori and Okkonen, 2012).

A vital component in knowledge sharing is trust. According to Sharatt and Usoro (2013), the trust in someone else to give him the required knowledge allows the individual to obtain vital information and work to achieve common interests. Trust is the main factor for sharing knowledge and it is recognised as a determinant of the effectiveness of knowledge-sharing. Confidence plays an important role in motivating the participants in the exchange of knowledge which are from person to person, person to group or group to group (Sharratt and Usoro, 2013). Moreover, Aliakbar, Yusoff and Moghaddam (2013) believe that if three factors are present (ability, benevolence and integrity) there will be trust and these factors are complementary to each other in a positive way for the exchange of knowledge through the Internet.

Sharratt and Usoro (2013) also have different views about these considerations. First of all, they believe technical infrastructure to be an important factor. Information technology can facilitate collaborative work and enable the knowledge transfer process. They claim that if both lay people and experts find the virtual community to have a high quality security system, they will be more willing to share their knowledge. Also, the variety and range of knowledge and expertise available attract members into exchanging their knowledge so that they can help create new knowledge.

The concept of reward is a big issue in the motivation of employees. Liao, To, and Hsu (2013), believe that if the organisation wants to motivate the employees they should put incentives in place. These rewards could be salary increases, performance bonuses, or any other monetary incentives. Even on a personal level, when the members are simply rewarded for only sharing their experience, it creates a psychological effect and they will become more productive. Also, interviews with staff to determine the most important factors that motivate the exchange of knowledge will be conducted. Ultimately, the views of the staff on the exchange of knowledge on the Internet between employees and companies and the codification of the most important incentives will be accessed through a combined method of a multiple choice questionnaire and open interview technique.

2.9 Knowledge Sharing in Health Sector

Knowledge sharing in the health sector "*As a hospital is organized with professional manpower in many different occupations, there are conflicts among different groups, and professional, administrative and non-professional groups are all mixed together. As it is operated 24 hours a day, it is generally very difficult to manage the human resources of the organization. Furthermore, values like service, autonomy, sincerity, justice and confidentiality that the medical professionals pursue can also make knowledge sharing difficult"* (Kim, 2013).

In their research Alhalhouli, Bin and Abdullah (2013) targeted hospitals that have simple techniques for the exchange of knowledge between professional and non-professional staff. They determined the obstacles that prevent stakeholders in Jordanian hospitals from sharing their knowledge and they have developed a conceptual model, based on the Theory of Planned Behaviour (TPB) and Technology Acceptance Model (TAM), to improve our understanding in terms of the factors, which affect the knowledge-sharing behaviour of knowledge workers in the Jordanian hospitals, a conceptual model, to improve and encourage stakeholders to share knowledge Finally, to achieve the goal of building the Model they did a survey, conducted interviews and analysed the results which were that stakeholders preferred to use face-to-face and workshops rather than the model.

Asemahagn (2014) conducted research in an Addis Ababa health bureau in Ethiopia. The research targeted 320 health professionals working in different hospitals who were willing to share knowledge and provide assistance. Data entry and analysis were done using Epi-Info version 3.5.4 and SPSS version20 respectively. Descriptive statistics and multivariate regression analyses were applied to describe the study's objectives and to identify the determinants of knowledge-sharing practices respectively. He applied a questionnaire which depended on age, sex, experience, salary, job satisfaction, professional category and the reasons for job satisfaction. On the results he said "*Most of the respondents approved the need of knowledge and experience sharing practices in their routine activities. Nearly half, 152 (49.0%) of the study participants had knowledge and experience sharing practices. A majority, 219 (70.0%) of the respondents showed a willingness to share their knowledge and experiences. Trust in others' knowledge, motivation, supportive leadership, job satisfaction, awareness, willingness and resource allocation are the determinants of knowledge and experience sharing practices. Supportive leadership, resources, and trust on others' knowledge can enhance knowledge and experience sharing by OR = 3.12, 95% CI = [1.89 - 5.78], OR = 2.3, 95% CI = [1.61- 4.21] and OR = 2.78, 95% CI = [1.66 - 4.64] times compared with their counterparts respectively.*"

2.10 Conclusion

In this chapter, we have presented the concept of knowledge management and knowledge sharing, focusing on the health sector, analysing current and future applications, and describing the barriers to sharing knowledge that could arise between employees in hospitals.

3 USABILITY

3.1 Introduction

In this chapter we introduce the concept of usability and the major strategies that could be used to test systems usability. Today, a lot of large, highly efficient systems and software have developed in the healthcare field. These have different goals, effectiveness and quality that need to be updated constantly and errors recovered. Testing systems helps to determine their effectiveness, limitations, weaknesses and strengths.

There are a lot of testing systems models, focusing on specific aspects of the system such as functionality, reliability, efficiency, usability, maintainability, portability, acceptance, security and so on. Each type of model largely measures the system in a specific manner. For example, if a researcher wants to test the acceptance, he can find ready models in many aspects of his system and he chooses what fits his research, as well as each model's search method and the method of examination results. The general aim of testing is to affirm the quality of software systems by systematically exercising the software in carefully controlled circumstances. Also the real test is to find system errors that have not been discovered yet and then analyze and compare the results. (Luo, n.d.)

In this research, we will focus on usability testing. In this chapter we will also provide a definition of usability. We will apply two of the most important models in usability and compare their results. We will examine previous research that examined the usability in healthcare area and compare them with this research.

3.2 Definition of Usability

(Shackel and Richardson, 1991) defined usability as follows: "*the capability in human functionality terms to be easily and effective by the specified range of users, given specified and user support to fulfil the specified range of tasks, within the specified range of environment scenarios". The definition of usability might be the capability to be used by human easily and effective where*

- *Easily : to be specified level of subjective assessment*

- *Effective : to be specified level of human performance “*

(Nielsen, 1993) defined usability is a process whereby the usefulness of a product or system is assessed through two aspects, its utility and its usability. Utility refers to a product’s capability to carry out an intended function. Usability refers to how easy users find it to accomplish that intended function.

3.2.1 Definition of Usability Test

Usability testing is to identify the areas where people are struggling when dealing with a product or software and give recommendations for designers and developers to improve the product or software. Also it helps designers and programmers to understand who is really using the product and help them to improve the product. In a typical usability test, real users try to accomplish typical goals, or tasks, with a product under controlled conditions. Researchers, stakeholders, and development team members watch, listen, collect data, and take notes.

Since usability testing employs real customers accomplishing real tasks, it can provide objective performance data, such as the time taken on a task, error-rate, and task success. There is also no substitute for watching users struggle with or have great success in completing a task when using a product. These observations assist producers and developers to improve the product and give alternatives and solutions to the problems of the system and which helps to achieve a better product.

3.2.2 Characteristics of Usability Testing

If the researcher decided to work on a usability test there are four effects: characteristics of defined objectives, real users, real tasks and early and iterative testing. (Miami University of Ohio, 2004)

- Clear objectives and goals help researchers design an experiment well and putting tasks that help their search and also the analysis of the results will be more accurate. For example, if there is a test for the viability of learning, the researcher must specify if he or she is testing for new users or users with experience. If the test is for both it could be a lower accuracy search. (Miami University of Ohio, 2004).

- An effective usability test monitors real tasks. There are many models to test usability, which will be mentioned later. Regulations vary in the environment and in different user capabilities. The researcher must choose the appropriate method or model that suits and serves his research. The tasks required, the type of users and the type of system must be chosen carefully making sure they serve the search results.

- An effective usability test is conducted early on. In the advanced stages one must also practice usability testing when the product is being designed. Early testing can assist the developers of the prototype refine specifications to ensure that the product's design fits the visual model that users have for it and to help it feel more intuitive to users (Miami University of Ohio, 2004).

3.3 Standards of Usability

(Nigel, 2009) Over the past 20 years, many experts have developed human-computer interaction (HCI). Experts develop terms of guidance, and the basic principles for the design, development and evaluation of systems and software characteristics. One of the major objectives of the international standards for examining usability is to provide safety, security and ease of use of the products and software (Dorina, 2015). International standards provide practitioners with a common technical language necessary in the development, acquisition, supply and evaluation of products and services and in communicating to other parties. They are also a means to ensure that the final product attains the desired quality. International standards have four goals and each goal includes standards or guidelines achieved.

1. The use of the product (effectiveness, efficiency and satisfaction in a particular context of use). Efficiency and effectiveness of the systems vary from one system to another. On large systems such as hospital systems, it is not necessary that all the system have a high quality. Parts of the system have efficiency and quality usability and other parts may be at a lower level. In laboratory systems, for example, the inquiry's properties and characteristics of

showing reports and results have a high efficiency whereas, other properties may be less efficient.

2. The user interface and interaction. The capabilities of users differ in dealing with user interfaces' regulations. The system is used by many types of people such as, disabled people, the elderly, new staff, people who have difficulty reading or have color blindness. There are sensitivity regulations that require the accuracy of a laboratory system in which decisions are made based on results and reports. Also, if systems are updated, new properties are usually added, which may be difficult for users to understand and handle easily. For these reasons, experts develop criteria and standards aimed at checking and achieving user satisfaction. These models usually measure the colors, sounds, navigating pages, display information on the screen where flexible control fits the needs of employees.

3. The process used to develop the product. After the application of standards and the identification of the limitations of the system, the developers cover mistakes and modify the properties of the systems to achieve the standards. In achieving usability standards, this greatly facilitates the user's life around the world. Also, if users find a system with a high performance and it achieves interface satisfaction, it will increase the performance of the staff, take a minute for decisions and accomplish the tasks quickly.

4. The capability of an organisation to apply user centered design. Most models measuring usability testing involve users. The participation of users in the tests and identification of problems in the system gives more accurate results and proposes solutions. (Bevan, 2001)

3.3.1 International Standards that Address Usability

The last ten years have seen the development and publication of a comprehensive range of international standards to support user-centred design and the development of easy to use interfaces. International standards are well known for specifying hardware and software interfaces and procedures for achieving quality. The standards are not only a useful source of reference for more experienced practitioners but can also provide guidance to organisations that are inexperienced in user-centred design, and can give credibility to the value of introducing user-centred methods. It is unfortunate that these standards can be expensive and owners of companies and institutions must pay to get them (Bevan, 2001).

There are five ISO standards that address the usability of information technology and interactive systems: (Marghescu, 2015)

- ISO/IEC 9126 – Part 1 (2000) - Information Technology – software product quality – this standard tests the quality of any type of software. It tests hardware and software of systems and making sure that all properties match the usability standards. Also it focuses on the process and user inputs and outputs of the system.

- ISO/IEC 14598 – Part 1 (1999) - Information Technology – Software product evaluation – Part 1. This focuses on defining and evaluating the usability of any product that is part of an interactive system and can be of nature software, hardware or service.

- ISO 9241 – Part 11 (1998) - Ergonomic requirements for office work with visual display terminals. Part 11. Stakeholders are involved in the system test. Make sure the system life cycle and the interaction between software and users.

- ISO 13407 (1999) - Human-centred design processes for interactive systems. They focus on the designs and user interfaces and user interaction with them.

- ISO 18529 (2000) - Ergonomics – Ergonomics of human-system interaction – Human-centred life-cycle process descriptions. (Marghescu, 2015)

3.4 Evaluations Models

Big systems contain software, computers and different user interfaces and the researchers measured the systems in many aspects such as functionality, reliability, efficiency, usability, maintainability, portability, acceptance, security etc. Each aspect has models and each model has aims chosen by the researcher according to his needs. Usability also has methods and researchers choose models that fit with their research.

3.4.1 Guidelines and Heuristic

The goal of the design of systems is to help make people's daily lives easier. Furthermore, these guidelines serve a lot of aspects such as industry products, software, architecture, hardware industry and computers. Also it assists in providing solutions and alternatives if the user has encountered a problem when dealing with the product. There are a lot of guidelines and heuristics are followed by product makers and programmers when designing their products whose sole purpose is to achieve usability (Fourcan, 2014).

All guidelines and heuristic have goals which must be achieved when they are applied.

- Focusing on User: Designers should support end-users because basically users like to give priority to their task and to achieve their goals. Designers know that users don't care how the company makes a product.

- Finding Alternative: Designing is about creating alternative options and solutions, it is not about choosing from multiple options.

- Using Prototype: Designers test their solutions by the application of models, sometimes using more than one model.

- Creating Appropriate Solutions: The designers have designed solutions as a solution does not fit all problems. They must be careful in the selection of the solution. (Fourcan, 2014)

There are some principles and guidelines that have helped many of the designs and products around the world in achieving usability and an easy life.

3.4.1.1 Shneiderman's Eight Golden Rules

The guideline Shneiderman"s Eight Golden Rules of interface design is put by experts who have long experience in the design of user interfaces. Experts wrote these rules based on recurring mistakes in software and related research. Boon.(n.d.).

3.4.1.2 Jacob Nielsen Ten Heuristic of Usability

These rules are used to evaluate the software and websites, rules designed to help speed up the resolution of usability problems for users. It does not need to be real users and researchers can apply the rules to the code and find errors (Cerretani, Zhang, Laing and Anand, 2008).

3.4.1.3 WCAG

Web Content Accessibility Guidelines (WCAG) where global standards are published by the Web Accessibility Initiative (WAI). These standards are aimed at people with disabilities. Disability is not necessarily someone confined to a wheelchair but anyone whose life is affected by a so-called disability. For example, color blindness and lack of reading lowercase or some kind of disability and standards that have been developed for it. (W3.org, 2015)

Before applying the standards, the user of interfaces and web pages should pass an exam and after that, the researchers can apply the standards. The results of the exam are:

Priority 1: Web developers must satisfy these requirements and conformance to this level is described as A.

Priority 2: Web developers should satisfy these requirements and conformance to this level is described as AA or Double-A.

Priority 3: Web developers may satisfy these requirements and conformance to this level is described as AAA or Triple-A. (W3.org, 2015)

WCAG It features 14 standard and each standard specific characteristics. All standards of Guidelines and Heuristic will be mentioned in the table below.

Shneiderman's Eight Golden Rules	Jacob Nielsen Ten Heuristic of Usability	WCAG
1. Strive for Consistency: All actions such as layout, terminology, command use, sequences and so on should maintain consistent sequences.	1. Visibility of system status. The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.	1. Provide equivalent alternatives to auditory and visual content.
2. Enable Frequent Users to use shortcuts: There are so many shortcuts such as macros, special key sequences, abbreviations which are used to take action very quickly.	2. Match between system and the real world. The system should speak the users' language, with words, phrases and concepts familiar to the user. Logical sequence to display information.	2. Don't rely on colour alone
3. Offer Informative Feedback: System feedback is very important for all kinds of actions. So for all user action, system should provide proper feedback.	3. User control and freedom. Users' access to functions by mistake, system gives the opportunity to return without problems.	3. Use mark-up and style sheets, and do so properly.
4. Design Dialog to Yield Closure: So that after completion their task user will know when they have completed their task.	4. Consistency and standards,	4. Clarify natural language usage
5. Offer Simple Error	5. Error prevention, best of	5. Create tables that

Handling: Allowing users to make mistakes and give them simple instructions to resolve.	error messages is to avoid mistakes and identify the problem.	transform gracefully.
6. Permit Easy Reversal of Actions: It allows the user to go back to previous page and this encourages discovery.	6. Recognition rather than recall. Make objects, actions, and options visible. Instructions for use of the system should be visible or easily retrievable whenever appropriate.	6. Ensure that pages featuring new technologies transform gracefully.
7. Support Internal Locus of Control: Design the system in such a way that an experienced operator desires that they are in charge of the system and the system responds to their actions.	7. Flexibility and efficiency of use. System meets the experts' and non-experts' needs.	7. Ensure user control of time sensitive content changes.
8. Reduce Short-Term Memory Load: This helps to speed up the system and the burden less memory.	8. Aesthetic and minimalist design	8. Ensure direct accessibility of embedded user interfaces
	9. Help users recognize, diagnose, and recover from errors	9. Design for device independence
	10. Help and documentation. Although the systems do not use good documentation, but he sometimes must provide the user with	10. User interim solutions 11. Use W3C technologies and guidelines 12. Provide context and orientation information 13. Provide clear

	documents such as agreement. (Nngroup.com, 2015)	navigation mechanisms
		14. Ensure that documents are clear and simple (W3.org, 2015)

Table 1 Compare between Guidelines and Heuristic

3.5 Testing Usability using the SUS and the QUIS Questionnaires

Some standards of Guidelines could be hard to be applied on systems and software in hospitals for two main reasons. First, the hospital environment is always busy and the system cannot be dispensed for the application of the standards by the researcher. Secondly, the privacy of patients, health laws and regulations may not allow researchers access to systems, fearing for their patients' privacy. So we will also employ a different evaluation strategy, preferring to collect our experimental evidence using a short and easy to be filled questionnaire based on the well-known System Usability Scale (SUS) and the QUIS systems, that will be illustrated in this section**.** The questionnaire is a quick and cost-effective method to conduct and measure scores compared with other inquiry methods. Sam(n.d.).

3.5.1 The System Usability Scale (SUS)

(Bangor, Kortum and Miller, 2009) said, "*There are numerous surveys available to usability practitioners to aid them in assessing the usability of a product or service. Many of these surveys are used to evaluate specific types of interfaces, while others can be used to evaluate a wider range of interface types. The System Usability Scale (SUS) is one of the surveys that can be used to assess the usability of a variety of products or services*".

(Brook, 2013) developed the questionnaire over 25 years to show a few questions with more efficient results. SUS is used to measure how the user deals with systems and computers and it is extremely fast, secure and reliable in evaluation systems. One of the most important advantages of this questionnaire is SUS serves speakers and non-speakers of English because it focuses on the system rather than people. This gives an opportunity for a lot of organizations around the world to use the questionnaire (Finstad, 2006). The questionnaire is based on five main objectives:

- Effectiveness: whether people can actually complete their tasks and achieve their goals. In this questionnaire the researcher obtains information about human interaction with the system which has proven its reliability over previous research. SUS can be used with a system that deals with small samples or large whereas some questionnaires require a large sample. SUS allows researchers to compare the characteristics of a system with each other. Also it allows researchers to compare the characteristics of a system or the whole system with other systems. Brook (2013) says that a questionnaire of 8 to 12 people is sufficient to evaluate the system. This gives an advantage in the questionnaire when assessing some systems to hospitals often used by the trainees and professionals (Brook, 2013).

- Efficiency: the extent to which they expend resources in achieving their goals. As usual staff may fill in long and tedious questionnaires and perhaps do so in a hurry without focus. Also they might be asked about their opinions without having sufficient experience. This questionnaire does not need a long time and allows the respondent to give their opinions about the system's properties.

- Satisfaction: the level of comfort they experience in achieving those goals. The main goal of all usability models is to achieve user satisfaction and facilitate their life. Centric questions about their problems and the extent of their satisfaction with the system's properties. (Brook, 2013)
- To provide us with a measure of people's subjective perceptions of the usability of a system.
- To allow us to do so in the very short time available to us during an evaluation session.

Although there are a lot of advantages there are also some challenges in the questionnaire which are of concern to researchers. The best researchers who tried the questionnaire say that the application of the questionnaire on a single system's properties is better then applying it on two systems. If researchers want to compare two systems, they must choose a different model with SUS which achieves higher efficiency (Jarrett, 2011).

The SUS survey results do not differ either with a large or a small sample of participants . In both cases researchers discovered that it affects the decision-making. Finstad (2006) applied the SUS questionnaire on non-English speakers and he found difficulties with item 8 in the SUS: “*I found the system very cumbersome to use*.” If you do decide to use SUS, then it’s probably best to replace ‘cumbersome’ with ‘awkward’. Also, the number of questions is small and does not cover a lot of users’ problems so researchers used more than one model in a single system to achieve their goals (Jarrett, 2011).

The questions in the questionnaire will be detailed, as will its objectives and its application in the experiment’s design.

3.5.2 The Questionnaire for User Interaction Satisfaction (QUIS)

The Questionnaire for User Interaction Satisfaction (QUIS) is a tool developed by a multi-disciplinary team of researchers in the Human / Computer Interaction Lab (HCIL) at UMCP. The questionnaire was designed to assess user satisfaction with specific aspects of the human/computer interface. The team identified that most of the problems related to the collection in usability and user satisfaction. These problems relate to validation, reliability, and standardization problems. The team conducted the survey of more than seventy-two user interface mostly in laboratories. It proved successful in defining user interfaces problems and helped to improve systems (Harper and Norman, n.d.).

In this version of the questionnaire, it is divided in five sections (Overall reaction to the software, Screen, Terminology and System Information, Learning and System Capabilities) with a total of 27 questions. Each area measures the overall satisfaction with that facet of the interface, as well as the factors that make up that facet, on a 9-point scale (Martinez and Chen, 2005).

3.6 Usability Studies in Healthcare

In this section we report previous relevant studies in the field of testing system usability in healthcare. Fadhilah (2012) conducted research on usability in a dental hospital in Malaysia. Hospitals in Malaysia are still using simple systems that do not serve staff properly. The goal of this research is to improve the usability of the system through the application of Jakon Nielsen's 10 heuristics on Web pages and Health information management (HIM). He did a questionnaire with all the hospital staff - administration, dentists in the dental clinic, management staff of the dental clinic (Nurse) and patient (Visitor). Also, he applied Jakon Nielsen's 10 heuristics rules on the system. At the end and after analysis, he wrote a list of limitations to the hospital which helps them to improve their system and web pages.

Sittig, Kuperman and Fiskio (1999) pointed out that there are has been very little usability research on hospitals and it needs to be studied more. They researched in Evaluating Physician Satisfaction Regarding User Interactions with an Electronic Medical Record System in the Brigham & Women's Physician Hospital Organization (BWPHO). He applied The Questionnaire for User Interaction Satisfaction (QUIS) to 75 physicians and asked them when they answered to focus on three main aspects:

- clinical results review which allows physicians to view patient-specific results from the clinical chemistry, haematology, and microbiology laboratories, as well as freetext documents such as discharge summaries, operative notes, and radiology examination reports.
- ambulatory medical record which allows clinicians to record and review a patient's current medications, medical problems, allergies, visit notes, health maintenance data, visit history, and a to-do list.
- list management which allows clinicians to add and delete patients from their personal patient lists.

After analysis, the results show the highest in the area of "screen design and layout" and lowest in the area of "system capabilities", as well as graphics on each question to compare answers. Finally, they gave the hospital a list of limitations that can be applied to improve the system.

Sidnaa *et al*.(n.d.) conducted research on Usability Laboratory Testing to Define User Interface for Guideline Support in the Electronic Medical Record in laboratory. The purpose of this paper is first to describe the process employed to understand computer-based guideline-assisted clinical care workflow, the human computer interaction. Secondly, based on a sample of guidelines tested with this method we identified some features of a clinical information system needed to support guideline/clinical pathway supported care.

In this research, there are three types of usability guidelines: Adult and Paediatric Immunizations (Institute of Clinical System Improvement, ICSI), Community Acquired Pneumonia Diagnosis and Management (ICSI), and Diabetes Mellitus Management (ICSI). Like the previous research after the application of standards and analysis of the results recommendations were made to the laboratory to improve the performance of staff.

3.7 Benefits of Improved Usability

Most computer software in use today is unnecessarily difficult to understand, hard to learn, and complicated to use. Difficult software wastes the user's time, causes worry and frustration, and discourages further use of the software. (Bevan and Macleod, 1994). Many cutting edge technology companies, such as Microsoft, IBM, and Hewlett- Packard, have adopted usability testing as part of their product development processes by investing in usability labs. The companies applied usability tests repeatedly before, during and after the product launch. These companies have realized the significant benefits that accrue to the product including the elimination of errors, the fact that errors can be fixed more easily earlier in the development process, that improvements suggested early are more likely to be implemented, and that prototype testing is less expensive and more effective than testing the final product (Miami University of Ohio, 2004).

Usable software increases productivity and reduces costs. Difficult to use software takes a long time to use. Often institutions and companies' systems, including hospitals, have a long process that is tied with other systems and it requires time to accomplish tasks. This affects the performance of staff and delays in the delivery of results. Usability tests were introduced to investigate the determinants of systems and software through which developers can develop software (Bevan and Macleod, 1994).

The more usability tests are carried out on the product, the less the likelihood there is of errors. Better budget for a number of tests by a small number of participants. Tests reveal mistakes early and give an opportunity for developers to cover defects on the product. The sooner usability testers find problems the easier it is to fix them. (Nielsen, 1993) If initial testing helps identify problems in a product while it is still on the design table, it is easier and less expensive to fix. Finding and fixing problems early will reduce rework later in the product’s growth. If prototype developers find a problem late in the development life cycle, it is more expensive to correct the product. Redesign requires time and costs that were not part of the original Conducting Iterative Usability Testing (Bevan and Macleod, 1994).

The user may not know all the features of the software that do not benefit from the full service software. There are some minor problems that the user may ignore but this will affect his performance and time consumption. If the system added new features, the system makes sure that users are familiar with these characteristics. For example, in the Questionnaire for User Interaction Satisfaction (QUIS) test there is a section asking users if the system provides references and more information about the new characteristics. Usability tests make sure that employees do not need a long time to search for information or even question their colleagues on the system’s properties.(Bevan and Macleod, 1994)

Also, for the installation of a new system or update an old system, it requires training on the new features which can be costly. If the development of systems and software is based on the needs of users it will give more information about its use. Users do not need to waste their time in training as well as companies and hospitals.

Usable software increases employee satisfaction. Difficult to use software reduces motivation and may increase staff turnover.

3.8 Conclusion

In this chapter, the concept of usability has been defined, its importance explained and how it is used in healthcare. An explanation of the mechanism to evaluate the usability in general and in particular for hospitals was given, along with its goals and the difference between them. We examined the most important and most famous usability models, focusing and justifying our choice to perform the usability study using a questionnaire-based approach. The analysis of related works in healthcare confirm the choice of the SUS and QUIS questionnaires as the investigation tools, since these methods were successfully used in various prior studies.

4 LABORATORY INFORMATION SYSTEM (LIS)

4.1 Introduction

Doctors, nurses and staff take a long time to arrange and organize patient information in hospitals. Every day, the quantity of information about patients increases in hospital systems and this data needs to be accurate. Also, after putting the initial information about patients into the system, staff needs to add additional information such as booking appointments, treatments and diagnosis which must be accurate as well. There are a lot of systems in hospitals today which are expensive and complex that needs experts to train users as well as there being difficulty with maintenance and development in the event of a problem such as systems in the treatment of cancer. On the other hand, there are systems which are simple, easy to use, inexpensive and can be handled by doctors, nurses, interns and staff. These systems usually require easy maintenance and when there are better systems, they are indispensable. In both systems the complex and simple must be careful in dealing with patient data. It is crucial that mistakes are minimised because simple mistakes could cause a problem for the patient. For example, if a nurse added a treatment to a patient's file by mistake then the pharmacist gives the wrong treatment to the patient which will cause a serious problem.

A lot of companies have started developing and manufacturing systems and software that help staff to organize patient information in hospitals. As mentioned earlier some of the systems are difficult and need a lot of money to develop and in this case hospital managers dispense with old systems if they cannot be developed. In this paper, we review one of the most important systems used by many hospitals around the world to organize and arrange patient information as well as allowing for the sharing of knowledge with other employees. The Laboratory Information System (LIS) is one of the best systems that has proven successful in recent years. In this chapter, we will learn more about this system and what distinguishes it from other systems. Also, on the advantages and disadvantages of the system, we will examine what can help developers to identify the limitations of the system and to avoid them in the future.

4.1.1 Laboratory Information System (LIS) Introduction

History

Before 1980 there was a floundering in the collection and arrangement of patient information. They were using the manual system which requires time and effort and less accuracy. A number of laboratories and experts met and produced the first system that facilitates and arranges all patient information in the laboratory which was a single centralized minicomputer in 1982. A lot of factory owners in this system welcomed this and helped to develop and produce laboratories at that time. By 1988 the second-generation commercial offerings were tapping into relational databases to expand LIS into more application-specific territory. From 1995 to 2002, the system was developed to allow data traffic across process on a network. Also, the system was linked to other networks by wireless to allow for the exchange of files inside and outside the hospital. Finally, the latest version of the system in 2012 was marked to add some features that will be mentioned later.

4.1.2 What is the Laboratory Information System (LIS)

The Laboratory module is an electronic web-based application designed with high flexibility and ease of usage, implemented in single clinics and polyclinics. It is a complete management system that handles all business functions from patient management, results generating, to physician decision-making. The system enables easy interaction with the data as well as the capacity to update data. It is one of the most reliable systems in giving orders and then giving correct results which are stored in databases. Also, the system reports and exchanges information between hospitals and clinics around data concerning (the status of infection, immunology, and care and treatment status of patients).

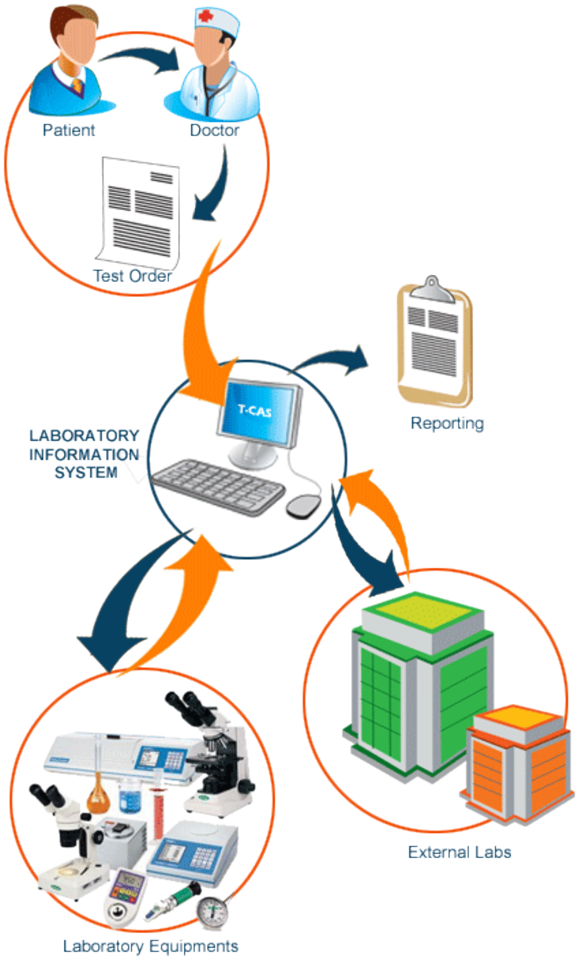

Figure 4 Departments Linked with the LIS system

The disciplines of laboratory science supported by LIS include hematology, chemistry, immunology, blood bank (Donor and Transfusion Management), surgical pathology, anatomical pathology, flow cystometry and microbiology. This article covers clinical lab which encompasses haematology, chemistry and immunology.

Because the system has a high efficiency in performance and meets privacy and security standards it can also be linked with other systems and supporting browsers. The LIS is used by a lot of institutions in healthcare files such as nursing homes, surgery centers, home health agencies, clinics, hospitals, and medical laboratories.

4.1.3 Objectives of LIS

The main objective of the system is to facilitate the management of data, the results of data storage, easier access as well as the capacity to update them at any time. Also, it manages the power to access information about patients in order to protect their privacy. There are also some goals that require time and effort:

- Many hospitals and laboratories suffer from the large number of papers and files of patients. Also, when renewing transferal papers from department to department it is possible to lose a large amount of documents or papers, which can be vital important. LIS means the establishment of a paperless environment while maintaining a digital database. All files and data can be stored in a local server or virtual servers. This method makes it easy to save and migrate and recover data in the event of loss.

- Optimize utilization of medical resources at the medical centre. Because the system was designed and developed by the experts in the field of laboratory, LIS is tied with a medical central system in which they can exchange data and raise the performance of staff with more accurate information and less errors.

- Increase efficiency of medical care outcome. The system gives feedback to users during the work on it and it gives alerts when there are mistakes.

- Monitoring and controlling the laboratory workflow process. Users can conduct through the system within the laboratory control samples and give correct results on time, for example, when entering the sample and putting it in the laboratory. LIS will recognise the patient information and link the information with the sample. This method facilitates the time and effort of the staff to get comparative information and the results of a patient's tests.

4.2 LIS Standards

When building systems for laboratories, hospitals and private clinics it must be taken into account what ensures the quality of tasks and process completion as required. There are tests and standards that measure the entire system and also tests that measure specific parts of the system. These specific parts are software or small networks which are tied with the system. A group of experts can decide to develop specific criteria to measure the efficiency of laboratory systems. The main purpose of these standards is to achieve high efficiency in management, safety and less errors. There are five main criteria for measuring the system and there are many other criteria that measure specific parts of the system such as user satisfaction, performance, scalability and usability.

ISO 9000

ISO 9000 is a series of standards that defines quality (ISO 9000, 2005) set forth by the International Organization for Standardization (ISO). These standards are part of the family quality management system and are designed to help institutions to make sure they meet the needs of customers. ISO 9000 standards are used by more than a million organizations worldwide today (Glavic and Korun).

ISO 17025

This consists of a private laboratory and specifications adopted by the International Organization for Standardization. The ISO 17025 standard contains five elements that are Scope, Normative References, Terms and Definitions, Management Requirements and Technical Requirements. The main purpose of these standards is to improve the Management Requirements and Technical Requirements. Management Requirements aims to apply the latest methods of management to ensure quality of management. Technical Requirements relate to the efficient Methods of Analysis and devices used and the methods of quality control analysis and reporting (Glavic and Korun).

Good Automated Laboratory Practices (GALP)

These practices were established by the Environmental Protection Agency (EPA). It is a set of regulations, guidelines and principles that ensure the reliability and credibility of the data analyst. These standards protect data from modification, loss, and corruption. They also focus on the collection, analysis, processing, and storage of data (Good Automated Laboratory Practices, 1995).

Electronic Signatures

The Food and Drug Administration (FDA) created standards and principles to raise the level of safety and maintain the privacy of patients in the laboratory. These standards apply electronic signatures to employees which differ from one report to another. This method does not apply to laboratories engaged in large and delicate projects, but work is underway to develop them to be used in all laboratories.

National Environmental Laboratory Accreditation Conference (NELAC)

NELAC is another EPA-related standard. The NELAC is sponsored by the EPA in an effort to develop a generally-accepted set of laboratory data management standards for all laboratories processing test data.

4.3 LIS Process

This process is a system through which samples and applications are processed in several stages. Requests may pass through more than one system on one process. Some systems in hospitals and laboratories are large, broad, complex and take days until the sample results show. The time taken to analyze the sample depends on the length and speed of the process. As mentioned earlier the system can modify its properties as needed in the laboratory, but this process will be mentioned for basic system stages (Hendrickson, Mennecke, Scheibe, Townsend and Pilson, 2005).

Analysis Request

When a patient is directed from GP, doctor, hospital or clinic to the laboratory, they shows evidentiary material and there is a specified request for analysis by authorized personnel from the responsible jurisdiction. After seeing all the paperwork the staff register all patient data within the system and also the samples for analysis, .

Evidence Collection and Submission

After the presentation of evidence all patient information will be recorded manually or electronically into LIS. Also the patient's personal information will be recorded in databases and it will be linked with the sample information. After this employees can add, delete and update information easily on all patients.

Evidence Login

After recording all of the patient's personal data and linking them with an information sample, the system produces a custom code for the sample patient, which is used throughout the period of analysis. Each sample has a code which is handled by the system and it records the time and date of entry and it gives reports during the analysis. This method gives more privacy to the patient while the staff deal with samples by the codes and they do not know the owners of these samples.

Distribution of Samples

The system should assist the laboratory personnel (specifically the section directors and analysts) with work lists, routing instructions, analysis scheduling, labeling, and chain of custody logging.

Schedule of Analysis

The system's ability to schedule the analysis based on workload and resources data. The system also benefits from previous analysis to help build highly efficient analytical tables.

Analysis

During the conclusion the system should provide measurement and result in the capture, documentation of analysis preparation procedures, test measurements, calibrations, and quality control processes.

Sample Preparation

Some samples need to follow specific steps of analysis in order to ensure the accuracy, efficiency and quality of results. The system registers the preparatory steps that the sample needs for analysis. This method gives more flexibility in dealing with the steps of analysis and determination based on sample need.

Sample Measurement

Some patients attend samples' analysis that they already have or they have some results which are not accurate enough. The system provides for the ability to add the results of the samples and reports either manually or electronically. Additionally, any self-checks, blanks, or calibrations should be captured as part of each result reported.

Verification and Correction

Most analyses require a check from another expert. This expert reads the results of the sample and modifies them and the work reports where there are numbers that are unclear or unusual. The expert adds all the amendments and comments and then analyses them once again. Re-analysis of samples is carried out by experts only and they have access powers whereas the laboratory staff do not.

Reporting

The system provides reports of samples at different stages during the analysis. Each sample report has all the characteristics of other reports. For example, the blood test report ID differs from other reports. The system gives both types of reports, electronic and paper.

Interpretation

The final conclusions drawn by the analysts from the test procedures are part of the final report and the system should provide analysts with the ability to provide their conclusions from the scientific analysis.

Disposal of Sample Materials

After the completion of the analysis, the system needs to get rid of the materials that are used during the analysis. The system gives reports about the location of use of materials, quantity and time. In the analysis, the system gives an alert to the existence of surplus and asks the analyst if he/she can he get rid of it or return it to the stock.

Biometric Identification

To achieve a high degree of safety, a lot of laboratory systems are used to identify solvency before the start of the analysis, or upon receipt of the result. The following are types of Biometric Identification Systems:

Techniques	Analysis
Retina Scanning	More methods of recognition accuracy, to identify the analyst through a layer of blood vessels behind the eye
Iris Recognition	Analyzes the pattern of the colored ring that surrounds the pupil of the eye
Finger Scanning	Fingerprint or thumbprint
Finger Geometry	Three-dimensional image of the analyst’s

	finger
Palm Scanning	Finger imaging on the Palm way
Hand Geometry	Full hand scanning on the Palm way (Lay hands on the device with a space between the fingers)
Voice Recognition	Voice recognition of analyst
Face Recognition	Examination of either a visible-light or infrared image. Analyzes the shape, pattern and positioning of facial features.
Signature Analysis	Analysis signing analyst

Table 2 Methods of Identify for users to collect results from the LIS system

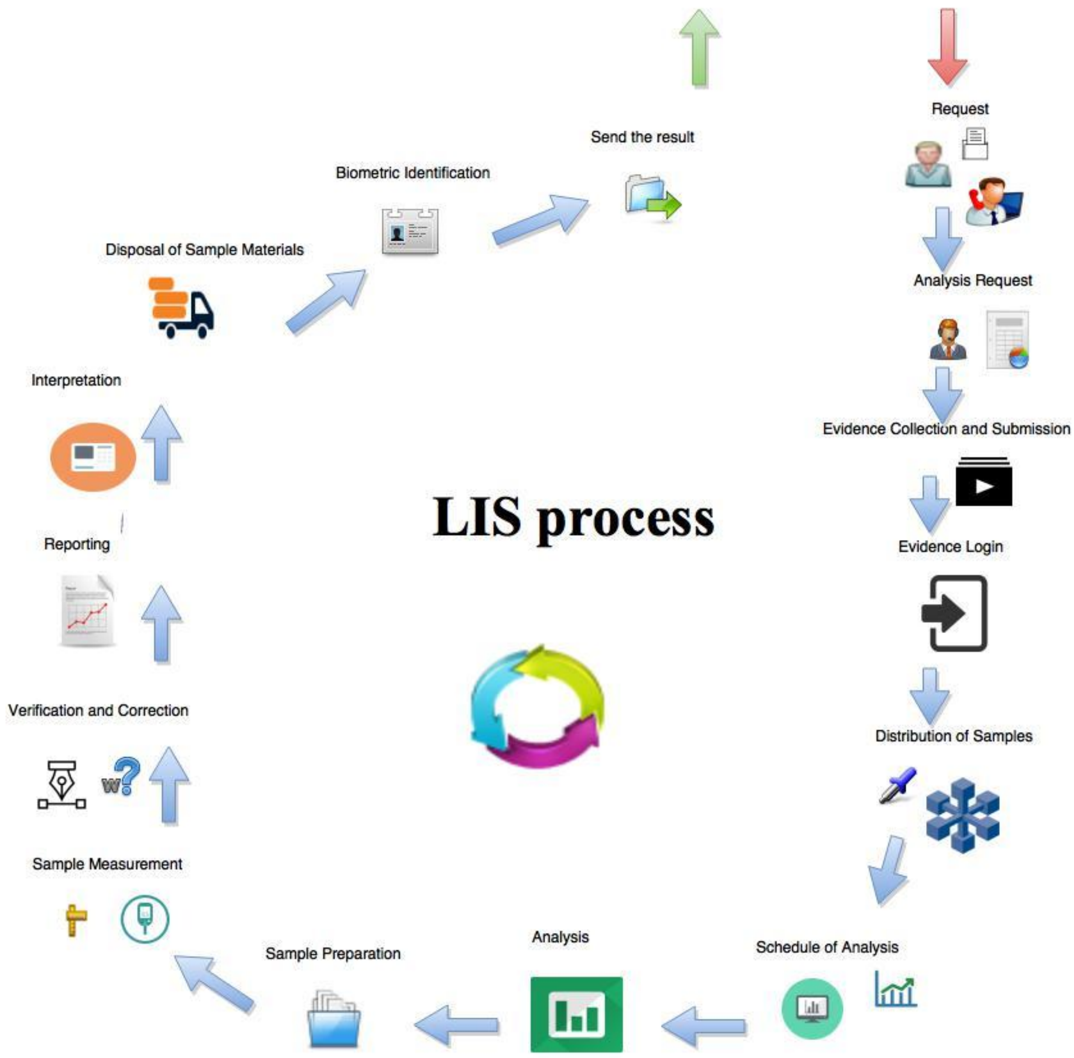

Figure 5 Process of LIS system

4.4 LIS Features

System consists of a core set of components that help build good environmental management. It has features which allow the system to add some ingredients that are commensurate with the needs of the hospital or laboratory. The system contains features favored by a lot of owners of private and public laboratories:

- Lab Inventory and Storage Management; there are many ways to manage information and the data of patients which vary from system to system. System features a bar code reader at the introduction of samples to laboratories. Each sample has a barcode and when reading the barcode system brings all the data related to the patient and when adding the same way when the barcode system automatically updates the patient data in the database Also, the system prints the reports and records of check samples and gives signals and alerts. When there have been some minor problems, the system does not wait for solutions from the user but offers appropriate solutions. All these features give management flexibility, are fast, easy to learn and lead to less mistakes.

- Security; LIS provides a secure platform from which laboratories can collect, approve, archive, retrieve, report, and analyze their data. The system provides complete updating and traceability with click-tracking, version control, and electronic signatures. It gives access to the powers of specific persons to get to the data and information of patients. For example, laboratory personnel working on the samples do not know any information about the patient data. They only know the sample data.
- Workflow Management; before installing the LIS system in any medical institution, the process used in the analysis of samples and patient data management must be taken into account. After that, LIS will be adjusted to fit with the old system in the laboratory. This method enhances the experience of the staff and it takes less time to learn because it is almost the same as the previous process with features. Also, users can define their own meta-data using a variety of attributes such as images, files, or hyperlinks. The queuing functionality of the LIS workflow component also aids in managing analysis requests from other systems, balancing the requests, and automatically queuing the associated samples, instruments, and analysts. Users can manage workloads by analyst and instrument, as well as schedule samples for testing to increase workload efficiency. The workflow feature also captures security data such as electronic signatures and the changes made to documents for version control. It makes the system auditable and compliant with regulatory standards.
- Data analysis; in an environment of laboratories and analysis work, there are plenty of digital data some of which may be equally matched with other data. This makes it difficult for the user to analyze and find the numbers and the differences required. However, the LIS system contains a set of functions that

support the analysis and mapping of data. Users can view data through data visualisation tools in the system. This method gives the most accurate display, with easier and faster results.

- Laboratory environment monitoring; laboratories often contain dangerous materials which are sensitive to human life and which are used to analyze samples. It is important to provide a very sound environment to achieve high efficiency at work. The LIS provides environmental monitoring functionality, and can aid in corrective and preventative measures by generating reports on who has used materials and instrumentation, whether they followed procedures/SOPs or not, and when they did so. Also within laboratories that deal with environmentally sensitive materials (such as laboratories that are in a warm environment) the system gives signals and alerts when there is pressure or an error.

Laboratories and hospitals contain a large amount of waste and these samples are always sensitive material or patient samples. The system gives reports on the amount of material and samples used in the analysis as well as emission rates from the system. This method helps laboratories to control the environmental impact with greater efficiency. The system is environmentally friendly, taking less samples and materials those creating fewer ratios and reports on waste.

4.5 LIS Limitations

Each system has its challenges which can be searched, developed and appropriate solutions found.

First of all, because the system is highly efficient, complex and tied to other systems there is a great difficulty in repairing mistakes. When there is an error stopping the system employees find it difficult to understand and repair it so they need to communicate with the company to send a team to fix the problem. Some problems need a long time to fix especially if the system is linked to other systems, causing crashes and overstock in patient outcomes.

Second, the system will give the final results to the user and explain the reasons for these figures. When there are figures which are unrealistic the employee needs to look behind these figures to comprehend. Also in some analyst reports data cannot be shared and so other departments are forced to print a hardcopy report. This method is contrary to one of the most important goals of the system which is the creation of laboratories which do not use paper.

Third, with the development of the system and system development tools, there are a lot of new programs and training is necessary. Among these programs is Data Visualization where users find a lot of difficulty in understanding numbers and images.

Finally, current reporting systems are limited in the number of data sources they provide. The systems are usually tied directly to the LIS and do not have the ability to bring information from other systems such as Pathology, Payroll, Materials Management, Billing, etc. Today, lab leaders need a comprehensive view of the laboratory, but are limited to managing information from each system in a fragmentary fashion.

5 EXPERIMENT DESIGN

5.1 Introduction

In this chapter we provide an explanation of our research methodology and we provide detailed description of the SUS and the QUIS questionnaires and how we adapted them to our research problem IT department in both Coombe and Hail Hospital understood the importance of usability and how it impacts on the performance of staff. Sixty-five employees in both hospitals participated in the experiment including two managers from each hospital while two employees were interviewed from both hospitals. The participants were asked to fill both the SUS and the QUIS questionnaires. In addition, to increase the efficiency of the research and give more accurate results an interview will be used with staff who are dealing with the LIS system.

5.2 Research methods used.

In this research both Quantitative and Qualitative research will be used employing interviews and a survey. The application of both Quantitative and Qualitative helps to give more accurate results and when there are limitations in the Qualitative, Quantitative they will be addressed. For example, if a section on the questionnaire asks about the ease of learning the system, and this topic is also discussed during the face-to-face interview, then both answers will be compared in order to gain clearer findings.

We start this section by quickly describing the concept of qualitative and quantitative research, the usage of questionnaires as a research tools and then we will describe in details the SUS and QUIS questionnaires used in this research. We end the section describing the semi-structure interview, representing the qualitative methodology used in this work.

Quantitative and Qualitative Research

Quantitative and qualitative forms of research are commonly considered to differ fundamentally. Yet, their objectives as well as their applications overlap in numerous ways.

Quantitative research

This method is used for research that contains numeric data, a lot of information and dataset. The most common research objectives are Description Explanation and Prediction as well as focusing on a single theory and measurement through a lot of information. The data collected is usually numeric data using structured and validated instruments (closed-ended survey items, rating scales, measurable behavioral responses). The format of the final report is statistical including correlations, comparisons of means, and statistically significant findings. (Comparison of Quantitative, Mixed, and Qualitative Approaches to Educational Research, 2004)

Qualitative research

Qualitative research is a method of enquiry that can provides a much more in-depth study, often at the expense of less broad results. The type of data collected is narrative data using semi- or unstructured instruments (open-ended survey items, interviews, observation, focus groups, documents). The final report is narrative in form, including a contextual description, categories, themes, and supporting respondent quotes. (Comparison of Quantitative, Mixed, and Qualitative Approaches to Educational Research, 2004)

5.2.1 Questionnaire

It is a series of questions designed to gather information from specific people. The questionnaires are designed to get the results of statistics and graphics. The most important benefit from the work of questionnaires is that it is inexpensive and easy to design. Also, the questions in questionnaires are simple and easy for the reader and also the analyst of the data. There are two types of questionnaire, an open-ended questionnaire which asks people about their opinions on a subject and closed-ended questionnaire which gives people multiple answers and they choose one answer.(Data Collection Methods for Program Evaluation: Questionnaires, 2008)

There are models for many questionnaires that achieve specific targets in advance. In this paper, we will use two models and each model has goals. Each model gives information on questions about a particular topic.

The first section of the questionnaire contains private information such as age, experience, years of work, qualification and the type of employee - nurse, doctor employee or trainee. This helps to give the stats and more precise information about the questionnaire and gives an opportunity to compare these questions. For example, with a qualification type question, comparisons may be made between types of qualifications and the impact or not on skills necessary when dealing with the system.

5.2.2.1 Questionnaire for User Interface Satisfaction (QUIS)

The questionnaire for user interface satisfaction (QUIS) takes users' views and evaluates user acceptance of a computer interface. This model contains five groups and each group has specific questions and over 27 questions. It usually takes about five minutes to resolve these questions and this helps to save time because the hospital laboratory staff are always working in a very busy environment (Stanton, Salmon, Walker, 2005).

- Ease of use: the questions in this group will be about all users' reaction and the details on the screen. It is very important to know the first impression about the system before you start to answer the other questions. In this group there are six questions and options for each question from 0 to 9. The multiplicity of options and figures for each option gives an opportunity for employees to express their opinions with precision. On the other hand, it gives the analyst precise proportions and very important information about the staff's views (Akıllı, G., 2005).
- Consistency: the questions in this group will be about the position of messages on screen, computer terminology is related to the task and error massages. Many of the regulations can be in terms that are incomprehensible which causes confusion for users. Systems and software makers are trying to use understandable and simple language because the system is employed in different countries and languages around the world. It supports non-English languages such as Arabic so the integrity of the language and the clarity of the reforms is so important for other languages. This section starts by asking users about clarity terms when they enter the sample to the system. After that, the ease of the terms and requests for samples on the sample system are addressed.

Next, the computer gives information about its progress during the analysis of samples. Finally, it addresses possible message errors if any.

- System capability: the questions in this group will be about reliability, correcting mistakes, users' experiences and speed. Many hospitals and laboratory managers want faster and more reliable systems. In this section questions are asked about the impression of the staff of the system's speed because the system helps speed the completion of tasks and prevent stockpiling. One of the objectives of this section is reliability and ensuring that the users do not need to return a lot of time to experienced staff asking them about results. Also, when process sampling, the system gives alerts. If there are errors, the system automatically corrects and gives options for users. Finally, it is to ensure that the system's design is commensurate with all of its users, with all categories of non-barriers or difficulties. (Stanton, Salmon, Walker, 2005)
- Learning: the questions in this group will be about exploring new features, helping messages, learning how to do tasks and giving references. For installation of the system this requires updated training courses in new functions and these courses may take hours or days. Also it is important to give new trainees the opportunity to learn in a short time. The section starts by asking users who are new to use the system and whether the system allows users to experience new features of the system with the possibility of error without damage. Also it enquires whether the system is explicit and clear about the requests of users for work tasks and gives them references if they want more information about a characteristic.
- Screen: the questions in this group will be about reading characters on the screen, highlighting information, Simplicity, organization of information and sequence of screens. Since the system is used by many kinds of people, of course not all people have the same capacity. The system measures the ability of those who are disabled to deal with the system. This is directed towards disabled people not in a wheelchair but anyone who has a deficit in a specific ability such as color blindness and the inability to read big letters. These simple things lead to big problems. For example, if the system gives an alert in red and the user has problems with colors, it is possible that the user makes the

wrong decision. The department asked users about colors, lines and arranges information according to their importance.

The questions relate to human-computer interfaces and the responses are normally measured on an ascending scale from 1 to 10. This gives an opportunity for the employee to express his opinion accurately. Meanwhile the analyst can achieve more accurate results (Kaplan, 2005).

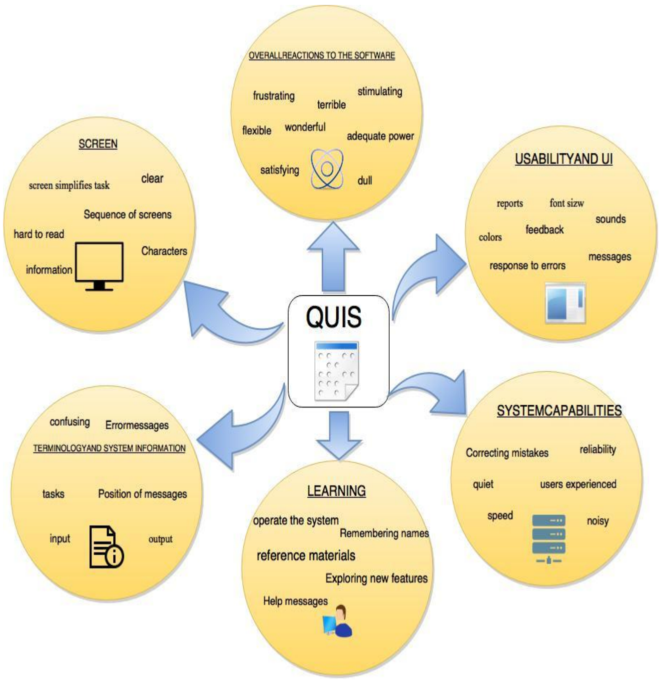

Figure 6 QUIS questioner groups

5.2.2.2 System Usability Scale (SUS)

SUS is a model created by John Brooke in 1986. It is a quick and reliable tool for measuring usability. This model measures software, hardware, websites and Mobile software. The main goal of this model is to measure three aspects. The System Usability Scale (SUS) is a simple, ten-item scale giving a global view of the subjective. The scale is shown in the next section of this chapter. It can be seen that the selected statements actually cover a variety of aspects of system usability, such as the need for support, training, and complexity, and thus have a high level of face validity for measuring the usability of a system.

Assessments of usability:

- Effectiveness: This goal focuses on two main aspects. The ability of users to complete tasks using the system, Ensure that all employees working on the system can complete tasks without any problems either with the system. The second aspect is the quality of the output of those tasks. After dealing with the system without any problems you should make sure that users do not have problems in the input and output information. Also, the questions in this point will be about the complexity of the system - do they need a technical person to help and how easy is the system to use, especially for new users or trainees with the system.
- Efficiency: this is about the level of resources consumed in performing tasks and this goal focuses on three aspects. First, the sources of information, because the system is large and is linked with other systems, a lot of the staff receive and analyze samples and returns sent to them and they perhaps do not know the source of the sample or the information. To know the sources of information and samples gives employees confidence in the decision-making and easier tracking of samples and sources of reliable information.

  The second aspect concerns the functions of the system. Sometimes, the laboratory staff only work with the major functions of the system and they might not benefit from other functions. Using all the functions of the system helps the quality, speed and efficiency in performing tasks. The last aspect is consistency, consistency and tasks running on the system without the need to transfer files and samples manually. The questions in this point will be about sources of information, functions of the system and consistency.
- Satisfaction: users' subjective reactions to using the system. The capabilities of users differ in dealing with the system's functions. For example, the experience of analysts is different from trainees' experiences dealing with the system. Here the focus is on user satisfaction with the system in general and its various abilities. The questions in this point will be about confidence in using the system and how easy it is to learn.

It consists of a 10 item questionnaire with five response options for respondents from 'Strongly Agree' to 'Strongly Disagree' (Brooke, 2014).

5.2.2 Semi-structured Interview

An interview is one of the main techniques of qualitative research. This type of interview employs open-ended questions to allow the interviewee to express his opinion more broadly. One of the disadvantages of the questionnaire is that it does not cover complex issues and questions and is usually general. The interview covers the defects and highlights the problems and discusses them with the interviewee. Also, the interview gives high validity by allowing the speaker to give an opinion on a problem in depth, explaining and proposing solutions. This type of interview is more flexible and through dialogue it can follow through on previous questions. The goal of this interview is to find points that are not covered by the questionnaire and get information from the interviewee (Whiting, 2008).

The interview includes 20 questions divided into three sections.

- Warm-up: It consists of general questions about the employee's experience and years of work and general questions. The aim of this section is to prepare more complex questions in the next section.

- Main interview: This section is the most important in the interview and it is divided into two parts. The first, has easy questions about the system in the opinion of the interviewee and some general points and the difficulties faced when using the system. In the second, the questions will be narrower about some issues. Most of them will explain some of the characteristics of the system and state the problems with proposed solutions and suggestions to improve the system (Whiting, 2008).

- Cool down: back to general questions about the system and thank the interviewee for the interview (Whiting, 2008).

In this work, a semi-structured interview will be used to obtain the views of people who use the system. The interviews will be with the people who use the LIS system namely doctors, nurses, staff and trainees. The goal of the interview is to get more accurate information from the users of the system.

5.3 Experiment Objectives

The main objective of the experiment is to measure the usability of the LIS system. First, results will be collected from the Coombe Hospital for both methods (SUS and QUIS), secondly the same experiment will be performed at the Hail Hospital. Finally, there will be a comparison between the results of the Coombe and Hail Hospital and there will be recommendations to both hospitals. The following are the objectives which will be targeted by the experiment.

- Provide an opportunity for IT departments in both hospitals to identify the challenges of the LIS system after the experiment.
- To collect feedback about the effect of usability of LIS using the SUS and QUIS model in both hospitals from participants through a survey and interviews.
- To compare the results obtained from the two hospitals in order to understand how cultural, linguistic and other difference can affect the perceived usability of LIS.
- Help developers by giving them recommendations for system development.

5.4 Hospitals' Situation

The installation and customization of the LIS system depends on the needs and requests of each hospital. Some small hospitals require basic systems, and not to be tied with other systems. On the other hand, some hospitals require large and complex systems, and need to be linked with other systems inside and outside the hospital. It is therefore important to describe the LIS installation present at both hospitals.

5.4.1 Coombe Hospital Situation

The Coombe Hospital has been using the LIS system for more than eleven years. The system is used by thirty-five employees with different qualifications, such as nurses, doctors, nannies and others from various departments. It is linked with Nannies, Homology, Chemistry micro, Histology, Cytology and the Virology program. Management uses Pat management program for the distribution of powers and staff access to the system. Doctors have permission to access all patient information in all departments.

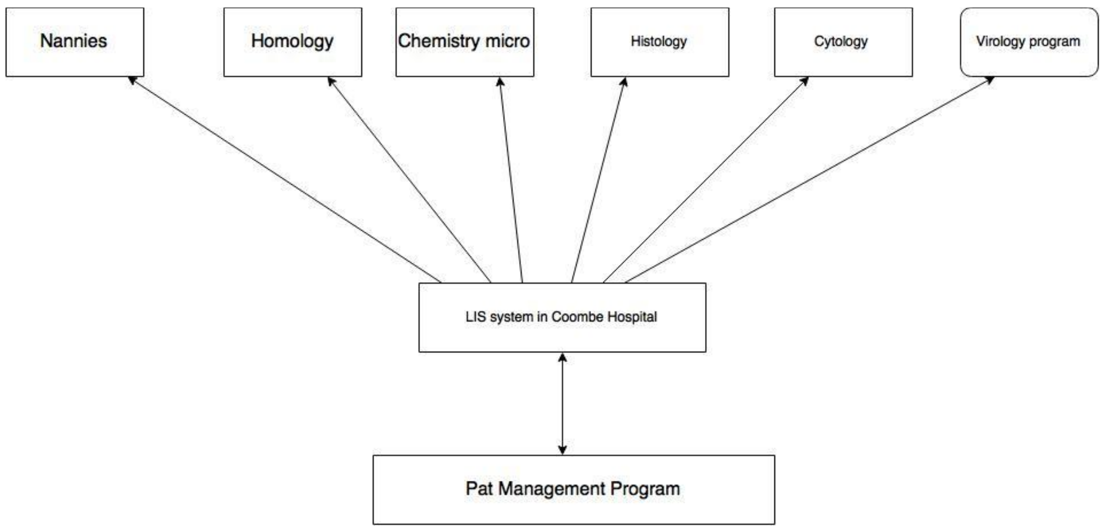

Figure 7 Departments linked with LIS system in Coombe Hospital

5.4.2 Hail Hospital Situation

The Hail Hospital has used the LIS system for approximately six years. Previously they used primitive medical systems which have taken away a lot of information. The LIS system is used by thirty-five employees with different qualifications, fifteen technicians with a higher diploma in laboratory, sixteen specialist laboratory staff and four doctors. The system is linked with departments in the hospital such as the Blood Bank, Chemistry, Microbiology, Histology, DNA and Hormones. All these departments continue with the laboratory through the LIS system to send and receive samples. They do not have access to all properties of the LIS system. They only have access to their samples and write reports and modify them. In addition, there is a distribution of access to the system for staff and other departments by the Records Department. The Records Department is the main controller of all information and patient records. They have access such as the access of the doctors to all of the patient's medical history.

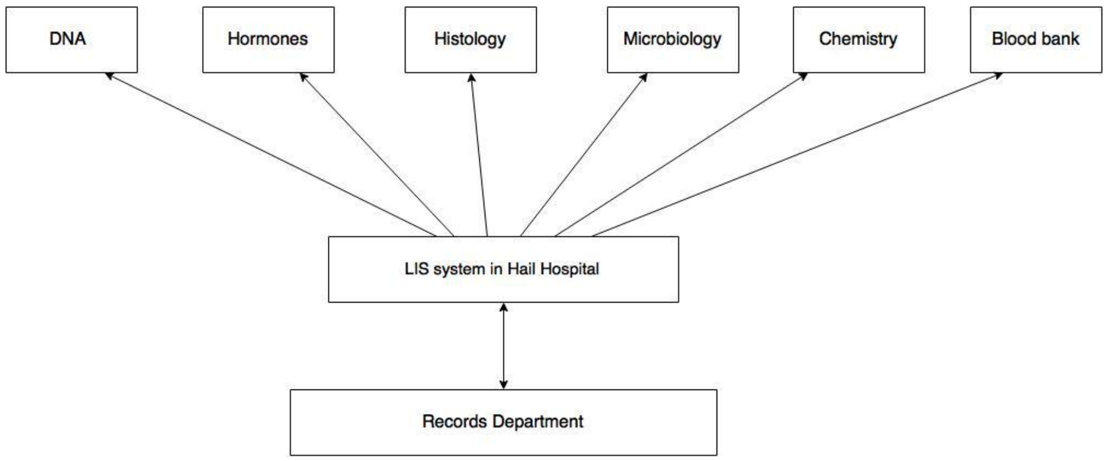

Figure 8 Departments linked with LIS system in Hail Hospital

5.5 Experiment's Challenges

There are some challenges facing the experiment that need to be resolved. Some of the challenges came from the survey and the interview while some of them were due to the arrangement of participants. .

- The use of Arabic language: because the experiment took place in Saudi Arabia and most of the participants who did the survey were Saudis. Also there are some international staff who speak Arabic in the lab and they also did the survey. When designing the questionnaire, it was ensured that the Arabic was written clearly and was easy to understand. When you compile some models, including terms from English to Arabic, some words give a slightly different meaning from their meaning in English. All these factors must be taken into account so some extra words were added to the questionnaire.

- Varying experiences of staff: Department laboratories in both hospitals contain a lot of staff with different qualifications such as doctors, students, trainees, employees and nurses. Sometimes each category has specific problems and sometimes they share problems. Also, years of work with the LIS system give staff confidence and experience in dealing with the system. The type of qualification, the number of years dealing with the system and the period of work in the hospital were taken into account in order to determine respect of each category of staff problems.
- Time and willingness to do the experiment. The hospital work environment is busy so staff often ignore questionnaires or leave it too late to do them. After obtaining approval from both hospitals, the prime department laboratories were interviewed in both hospitals to take staff details to communicate with them directly.

5.6 Experiment Process

After obtaining the approval of both hospitals, the questionnaire was written based following the QUIS and SUS specifications. The questionnaire was written in Arabic and English, and it was augmented with a set of demographic questions about user experience, working time and qualifications. After that, an appointment was made with the head of laboratories department in both hospitals (for Hail hospital it was a Skype meeting). Following their approval, the questions were distributed to the staff members. Finally, the answers to both the questionnaires and the interviews in both hospitals were collected and prepared for analysis and evaluation.

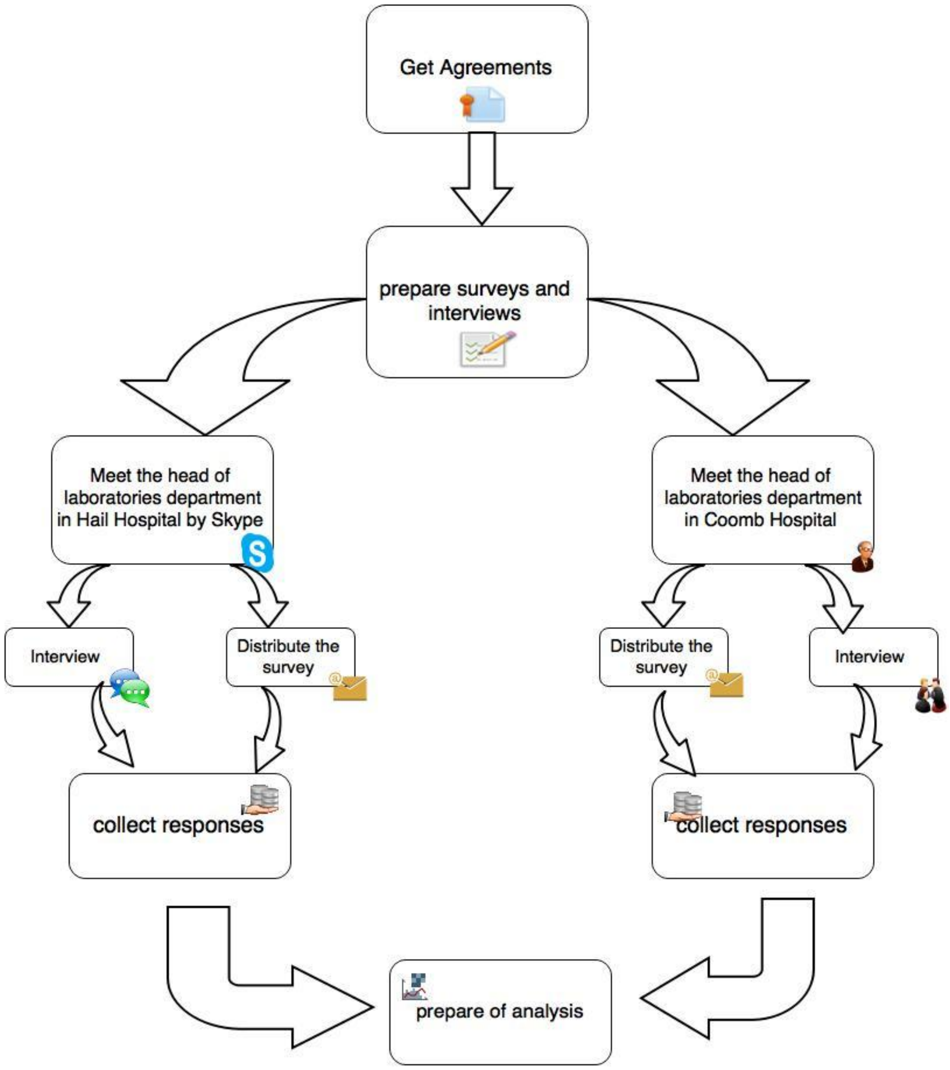

Figure 9 Experiment Process for both hospitals

5.7 Conclusion

In this chapter, the experiment design has been described. An overview of the quantitative and qualitative research methods used in this study was given along with an example of each type. We described the SUS and QUIS models and we presented the design of the questionnaire to be circulated among hospital staff. We have also provided an overview of the LIS installation in the two hospitals and described how the experiment was executed. In the next chapter, we will compare the results of both the models in the two hospitals.

6 EXPERIMENT RESULTS & EVALUATION

6.1 Introduction

Having explained the methods of analysis of both SUS and QUIS questionnaires, in this chapter we described how the experiment was implemented and executed. Moreover, we also describe the methodology used to analyze the data gathered, centered on a series of statistical t-tests. After that, the SUS questionnaire results and QUIS questionnaire results are shown for both hospitals. The differences between SUS and QUIS results for both hospitals are discussed with the aid of graphs. Finally, the results of the interviews are analysed and the perceived usability of the system discussed in details.

6.2 Feedback Collection

Feedbacks were taken from the participants using semi-structured interviews and surveys. After obtaining the approval of the hospital administration an appointment was set with the IT Department in both hospitals. In the Coombe Hospital, both the duration and way of doing the experiment were discussed. The email addresses of the laboratory staff were supplied and we decided to communicate directly with them and search for volunteers to be interviewed. With the Hail Hospital I discussed the experiment with the IT department over Skype. Hail Hospital has two mechanisms for communication between staff. Firstly, via email to send and receive official documents from the administration. Secondly, through the Whatsapp which is an application on smart phones. They have a group for only laboratory staff which they can exchange knowledge and questions. This group includes all the old and new employees, interns and doctors. They decided to send the questionnaire via email and WhatsApp, and also to do the interview with a volunteer.

Surveys

The questionnaire took the first week of the experiment. There were two different questionnaires for the Coombe and Hail hospitals. The Hail Hospital questionnaire was written in the Arabic language. The questionnaire was divided into three sections. The first section concerned general information about employees, such as sex, age, years of experience, the time they spent in the hospital and years of dealing with the LIS system. The second section, the System Usability Scales (SUS) model questions, consisted of ten questions with five options to answer from strongly agree to strongly disagree.

The third section was the Questionnaire for User Interface Satisfaction (QUIS) which is divided into six groups of questions. Answers in the QUIS section are number on a scale from 0 to 9. The results of both questionnaires were collected in two Excel files in preparation for analysis. Both questionnaires were written using the tool esurveycreator (www.esurveycreator.com), a non-free tool needed to support both Arabic and English languages.

Semi-structured Interview

The semi-structured interview is a common method in knowledge acquisition. The number of employees in both hospitals were approximately sixty five and one employee was selected from each hospital to conduct the interview. The interviews were always done with topics gathered from the survey and there were explored in depth. The reason for choosing the semi-structured interview was the need to explore the weaknesses of the questionnaire and receive more informed answers while giving employees an opportunity to express their opinions in a face-to-face context.

6.3 Data Analysis

In this section we describe the statistical tools used to analyze the data collected.

Standard deviation

Standard deviation is a measure of the data dispersion, it is used to measure the dispersion of data on the middle of the arithmetic, and it is calculated by taking the square root of the variance calculated in advance for such data. Calculating the standard deviation of a set of data is the arithmetic mean of the account data by dividing the sum of the data on the issue. Contrast account data by dividing the sum of squares of deviations from the values of the middle of the arithmetic on the (n-1). The standard deviation is calculated by taking the square root of this measure. (Mathsisfun.com, 2015)

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}$$

T-test

A t-test is a "*statistical examination of two population means. A two-sample t-test examines whether two samples are different and is commonly used when the variances of two normal distributions are unknown and when an experiment uses a small sample size*". (Investopedia, 2015)

There are several variation of the t-test according to the relation among the groups of items analyzed and their size.

One-sample t-test. In testing the null hypothesis that the population mean of a sample is equal to a specified value μ_0, one uses the statistic.

$$t = \frac{\overline{x} - \mu_0}{s/\sqrt{n}}$$

where x is the sample mean, *s* is the sample standard deviation of the sample and *n* is the sample size. The degrees of freedom used in this test are $n - 1$.

The two-sample t-test has two types to calculate data Paired and Unpaired sample t-test. First, the paired samples t-test is used when two separate sets of independent and identically distributed samples are obtained, one from each of the two populations being compared. Second the unpaired t test assumes that the two populations have the same variances (and thus the same standard deviation). The unpaired t method tests the null hypothesis that the population means related to two independent, random samples from an approximately normal distribution are equal. The unpaired test is used to test all the feedback, so it is needed to extracting the difference between the values (Statsdirect.com, 2015). Only the two types of unpaired and unequal variances are used. Assuming unequal variances, the test statistic is calculated as:

$$d = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad df = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}}$$

$$s_1^2 = \frac{\sum_{j=1}^{n_1}(x_j - \bar{x}_1)^2}{n_1 - 1} \qquad s_2^2 = \frac{\sum_{j=1}^{n_2}(x_j - \bar{x}_2)^2}{n_2 - 1}$$

where $\overline{x_1}$ and $\overline{x_2}$ are the sample means, s^2 is the sample variance, n_1 and $n_2$are the sample sizes.

In this research we used both types- a one sample *t*-test and a two-sample *t*-test. The one-sample *t*-test was used to show the results of data for one hospital and the two-sample *t*-test, unpaired, was used to compare the results of the two hospitals.

Critical Values. In hypothesis testing, a critical value is a point on the test distribution that is compared with the test statistic to determine whether to reject the null hypothesis. If the absolute value of your test statistic is greater than the critical value, you can declare statistical significance and reject the null hypothesis. Critical values correspond to α, so their values become fixed when you choose the test's α. Experts put a table that contains critical values based on the sample number. The number of laboratories in each hospital is thirty five and critical values for this number in are 1.69 and -1.69.

3.4 Presentation of the Results

In this section we present the result of our data analysis. For each question, we computed the standard deviation, the average scores, the number of answers and the t-test value. As mentioned, we use the t-test to check if there was any statistical significant difference between the answers. Calculations were done on both models, the SUS and QUIS, for both hospitals. In this section, the results of the SUS model and the QUIS model will be displayed. In the next section, we will discuss and compare the differences between the results and determine the strengths and weaknesses of each hospital.

6.4.1 System Usability Scales (SUS) model Results

The results of the SUS model were analysed with a one-sample *t*-test with the null hypothesis zero, representing the neutral score. One-sample *t*-test requires average values. Results were extracted from all the questions in both SUS models for both hospitals. Also, average values are offered on a graph to facilitate the identification of values for the readers. First we show the results for the SUS model in the Coombe Hospital and later the results of the SUS model in the Hail Hospital. Total results of each model will be shown and compared in the next section.

Coombe Hospital

System Usability Scales (SUS) questions	T-test	SD	AVG_Score	N
1. I think that I would like to use this system frequently.	0.2134	0.828	0.03125	32
2. I found the system unnecessarily complex.	3.4231	0.722	0.4375	32
3. I thought the system was easy to use.	0.3874	0.942	0.066667	30
4. I think that I would need the support of a technical person to be able to use this system.	0.3993	0.885	0.0625	32
5. I found the various functions in this system were well integrated.	0.4193	1.064	-0.09375	32
6. I thought there was too much inconsistency in this system.	1.1090	0.796	0.15625	32
7. I would imagine that most people would learn to use this system very quickly.	0.8864	0.79	0.125	32
8. I found the system very cumbersome to use.	1.1276	0.940	0.1875	32
9. I felt very confident using the system.	1.327	0.798	0.1875	32

10. I needed to learn a lot of things before I could get going with this system.	1.1500	0.768	0.15625	32

Table 3 Results of SUS model for Coombe Hospital (t-test versus neutral score)

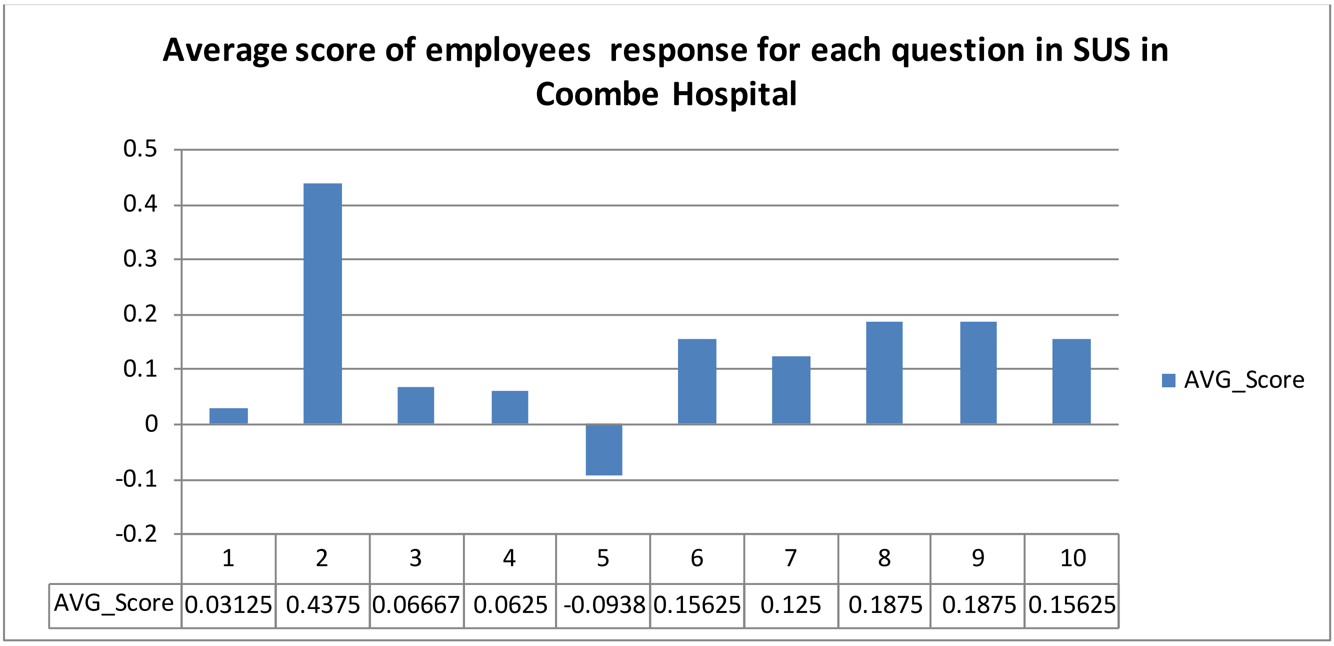

Table 4 Average score of employees response for each question in SUS in Coombe Hospital

From the results for the Coombe Hospital, the answer with the highest score is (*I found the system unnecessarily complex*) and it has the highest number for several reasons. First, the LIS system works in English which is the mother tongue of the Coombe hospital staff. Second, most of the laboratory personnel are highly experience people and they have worked for a long time in the hospital. Finally, there are many sources of the LIS system in English which they can easily access. In addition, (*I found the system very cumbersome to use*) and (*I felt very confident using the system*) had the second highest number. Even if the staff felt confident in using the system, they feel that the system is somewhat slow and it needs more speed. However, it is also clear on the graph that the response '*I found the various functions in this system were well integrated*' had the lowest number, confirming a problem in the complexity of the LIS system.

Hail Hospital

System Usability Scales (SUS) questions	T-test	SD	AVG_Score	N
1. I think that I would like to use this system frequently.	2.452852437	0.693413	0.321429	28
2. I found the system unnecessarily complex.	0.765981155	0.969712	-0.13793	29
3. I thought the system was easy to use.	1.5	0.7698	0.222222	27
4. I think that I would need the support of a technical person to be able to use this system.	5.535710023	0.764834	0.814815	27
5. I found the various functions in this system were well integrated.	0.222544244	0.83442	-0.03448	29
6. I thought there was too much inconsistency in this system.	1.176427513	1.445767	-0.32143	28
7. I would imagine that most people would learn to use this system very quickly.	0.334893783	1.14932	-0.07407	27
8. I found the system very cumbersome to use.	0.910345694	1.203329	-0.2	30
9. I felt very confident using the system.	1.784448779	0.754939	0.259259	27

10. I needed to learn a lot of things before I could get going with this system.	4.488981225	0.827338	0.689655	29

Table 5 Results of SUS model for Hail Hospital (t-test versus neutral score)

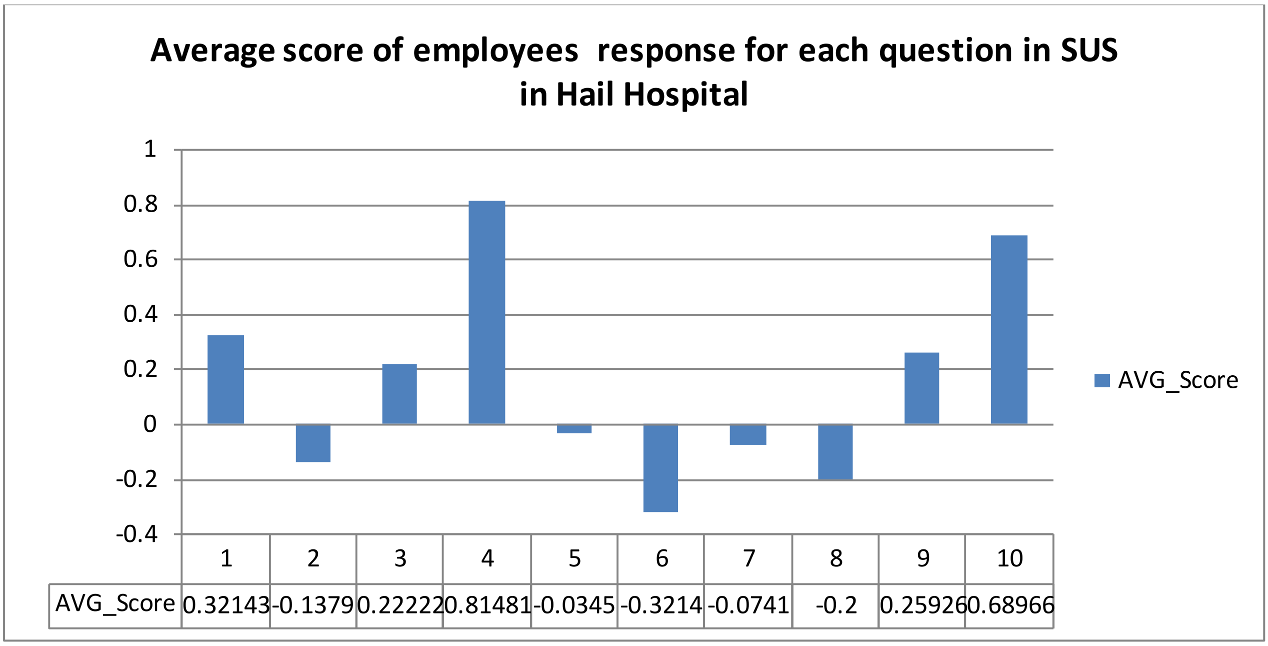

Table 6 Average score of employees response for each question in SUS in Hail Hospital

According to the table the responses with the higher score (=users agreed with the statement) were: *'I think that I would need the support of a technical person to be able to use this system'* and *'I needed to learn a lot of things before I could get going with this system'*. The interview with an employee revealed how new employees at Hail hospital need a two-week session led by a technical support team before they start working on the LIS system. The team helps staff if they encounter difficulties and continues working with staff until they become professionals. On the other hand, the response with the lower agreement was: *'I thought there was too much inconsistency in this system'*.

6.4.2 Questionnaire for User Interface Satisfaction (QUIS) model Results

In this section, the results of the QUIS model for both hospitals will be described. Each model contains six groups of questions. One-sample *t*-test was used to calculate each group and the null hypothesis is that the average score differs from the value of 4.5 (the neutral point, since the answers are from a scale from 0 to 9). The following tables present also the standard deviation, average scores, number of answers and the t-test value for each of the six groups and foe the overall QUIS questionnaire. As mentioned, we used the t-test to show the difference between the answers in the groups themselves. Below are displayed the results first for the Coombe Hospital and then for the Hail Hospital.

Coombe Hospital

Overall reaction to LIS system	**AVG**	**N**	**STD**	**t-test vs 4.5**
terrible/wonderful	4.030303	32	1.740777	-1.526339
frustrating/satisfying	4.1875	32	3.991064	-0.442939
dull/stimulating	3.84375	32	4.288315	-0.86561
difficult/easy	4.21875	32	2.928343	-0.54336
inadequate power/adequate power	4.34375	32	6.984707	-0.12654
rigid/flexible	4.5625	32	4.753288	0.0743808
Total	4.196891	193	2.741351	-1.53607

Table 7 Overall reaction to LIS system in Coombe Hospital

Screen	**AVG**	**N**	**STD**	**t-test vs 4.5**
Characters on the computer screen	4.71875	32	1.459234	0.84800438
Highlighting on the screen simplifies task	4.09375	32	5.940871	0.38682832
Organization of information on screen	4.1875	32	3.884565	-0.455065
Sequence of screens	4.1875	32	4.16599	-0.424303
Total	4.296875	128	4.079956	-0.563517

Table 8 Screen group results in Coombe Hospital

Terminology and LIS information Use of terms throughout system is:	AVG	N	STD	t-test vs 4.5
Use of terms throughout system	4.40625	32	1.598033	-0.3386419
Computer terminology is related to the task you are doing.	4.6875	32	3.328382	0.31867143
Position of messages on screen.	4.4375	32	3.518367	-0.1004892
Messages on screen which prompt user for input.	4.53125	32	2.216762	0.07974547
Computer keeps you informed of its actions.	4.466667	30	2.86434	-0.0637404
Error messages.	4.03125	32	3.89097	-0.681485
Total	4.426316	190	3.036794	-0.334461

Table 9 Terminology and information group results in Coombe Hospital

Learning	AVG	N	STD	t-test vs 4.5
Learning to operate the system	3.71875	32	1.565934	-2.822504
Exploring new features by trial and error	3.9375	32	2.722878	-1.168645
Remembering names and use of commands	3.90625	32	3.312058	-1.014093
Tasks can be performed in a straightforward manner	3.967742	31	3.221126	-0.920611
Help messages on the screen	3.6875	32	3.202782	-1.435304
Supplemental reference materials	3.875	32	2.997395	-1.179565
Total	3.848168	191	3.644397	-2.471806

Table 10 Learning group results in Coombe Hospital

Most of the answers show a lack of satisfaction with the process of learning the system but they did not reach critical values. Clearly from the table, most of the staff members find it hard to operate the system. They commenced work on the pre-opened the LIS system and they completed their schedule without closing the system. In the event of system interruptions at work, staff might not turn it back on again.

System capability	AVG	N	STD	t-test vs 4.5
System speed	4.625	32	1.556237	0.45436947
System reliability	4.46875	32	2.849925	-0.062055
System tends to be noisy-quiet	5	32	2.686773	1.05272271
Correcting your mistakes	4	32	3.292985	-0.858925
Experienced and inexperienced users' needs are taken into consideration	4.09375	32	2.155344	-1.0662213
Total	4.4375	160	2.884351	-0.2740816

Table 11 System capability group results in Coombe Hospital

Usability an User Interface	AVG	N	STD	t-test vs 4.5
Use of colours and sounds	3.972973	32	2.41721	-1.233019
System feedback	3	32	4.52424	-1.87152
System response to errors	3.970588	34	3.061792	-1.002492
System messages and reports	4.21875	32	2.716234	-0.585733
System clutter and UI “noise”	4.967742	31	2.522737	1.03232183
Total	4.018072	166	4.496757	-1.380818

Table 12 Usability an User Interface group results in Coombe Hospital

In the tables, a positive value of the t-test means that the average score is higher than the neutral point and vice-versa. Table 8 shows how Coombe staff is overall not satisfied with the system (the average score differs significantly from the neutral scored, t-value= -1.58). Regarding the six components of the QUIS questionnaire, all of them have a negative score below the neutral point, with significantly statistical differences for the learning-related group, that scored a t-value of -2.47. The user interface also scored poorly, with a t-value of -1.38 (significant at 90% level). Therefore the Coombe’s staff seems to be very unhappy with the learning supports provided by LIS and its interface, while they are moderately dissatisfied with all the other QUIS components.

Hail Hospital

Hail' staff has an overall positive opinion of the LIS system, even if the t-value of 0.53 is not enough to create statistical significance. Regarding each of the six QUIS components, the staff is satisfied about five out of six categories, with statistical significance for the screen and user interface group (all t-values > 2.1). However, it is interesting to notice how the staff were dissatisfied with the learning aspect of LIS (t-value= -2.51), which suggests a system effective but difficult to learn.

Overall reaction to LIS system	**AVG**	**N**	**STD**	**t-test Vs 4.5**
terrible/wonderful	4.571429	32	1.827371	0.221115997
frustrating/satisfying	4.62069	29	2.453487	0.264902017
dull/stimulating	4.068966	29	2.079817	-1.11605571
difficult/easy	4.827586	29	1.650906	1.068568162
inadequate power/adequate power	4.37931	29	2.458896	-0.26431932
rigid/flexible	5	29	3.24303	0.830267585
Total	4.578035	173	1.909662	0.537469903

Table 13 Overall reaction to LIS system in Hail Hospital

Screen	**AVG**	**N**	**STD**	**t-test Vs 4.5**
Characters on the computer screen	5.066667	32	2.038109	1.57280622
Highlighting on the screen simplifies task	5.62069	29	2.307681	2.615221916
Organization of information on screen	5.392857	28	2.299256	2.054819112
Sequence of screens	3.857143	28	2.559211	-1.32919085
Total	4.991304	115	2.444684	2.155146596

Table 14 Screen group results in Hail Hospital

The screen group (table 14) is the most important group in the usability test. It shows significant results which may be useful for developers in Hail Hospital. According to the table, highlighting on the screen simplifies the task and the organization of information on the screen is not causing problems for employees. Through the interview confirmed that there is large equipment and clear screens in laboratories. However, this large equipment has disadvantages. For example, when you show a sample the LIS system displays a lot of information that is not necessary, such as employee records and personal information. This data is given on one page and the LIS system does not give employees opportunities to choose the information they require. In addition, the small size of the sentences and letters is an obstacle to identifying the tasks correctly. The system gives a lot of tasks in a single page in small sizes. This could explain the negative score for the *sequence of screen* questions.

There is no difficulty (table 15) in understanding the terms and explanation of the tasks in the system. Actually, the feature of the LIS system that sends messages to employees about the input of information and error messages seems to wirk well.

Terminology and LIS information Use of terms throughout system is	**AVG**	**N**	**STD**	**t-test Vs 4.5**
Use of terms throughout system	4.689655	32	1.99709	0.537207401
Computer terminology is related to the task you are doing	4.413793	29	1.358056	-0.34184045
Position of messages on screen	4.482759	29	2.479702	-0.0374433
Messages on screen which prompt user for input	4.413793	29	2.014524	-0.23044572
Computer keeps you informed of its actions	4.793103	29	1.97901	0.797575932
Error messages	5.034483	29	2.211731	1.301368749
Total	4.637931	174	2.164229	0.840685326

Table 15 Terminology and information group results in Hail Hospital

Learning	**AVG**	**N**	**STD**	**t-test Vs 4.5**
Learning to operate the system	3.965517	32	1.917188	-1.5770447
Exploring new features by trial and error	3.551724	29	2.124589	-2.4035808
Remembering names and use of commands	4.310345	29	1.931778	-0.5286966
Tasks can be performed in a straightforward manner	4.724138	29	1.820607	0.662976603
Help messages on the screen	4.758621	29	2.610759	0.533452083

Supplemental reference materials	3.617647	34	2.052939	-2.5061425
Total	4.139665	179	1.887955	-2.5535339

Table 16 Learning group results in Hail Hospital

It seems that the majority of employees are dissatisfied with the way they learn the system (table 16), despite their 2 weeks compulsory training. If the new staff begin to work on the system, they take a two-week course to learn it. During the session they study basic aspects of the system allowing them to discover errors and System Properties. Upon completion of the session and when they commence working, if they encounter problems in the system they can communicate with the support team to solve them. Also, they can suggest some points that improve the system's performance. However an explanation of the poor score could be that once they start working in the lab they are not allowed to explore new features by trial and error, but they should ask a technical support team about every single problem.

System capability	AVG	N	STD	t-test Vs 4.5
System speed	4.931034	32	1.498563	1.627092095
System reliability	5.482759	29	1.902639	2.781567216
System tends to be noisy-quiet	5.103448	29	2.296844	1.414840627
Correcting your mistakes	4.206897	29	2.574631	-0.6130626
Experienced and inexperienced users' needs are taken into consideration	2.448276	29	2.99074	-3.6943611
Total	4.434483	145	3.554042	-0.22198164

Table 17 System capability group results in Hail Hospital

Referring to table 16, the majority of employees have trust in the system and they do not consult doctors and people with experience before sending results. Based on the interview conducted and the analysis of Hail's LIS implementation, we believe this trust is due to two main reasons. First the new system is nearly five years in the hospital. The existence of a dedicated team supporting staff decisions when dealing with the system enhances the confidence in the system. Secondly, the system support team update every year and with updates change icons and some properties. These changes fit the needs of employees and give more confidence and goodwill. On the other hand, many staff agree that the system does not distinguish between the expert employees and non-experts when dealing with the properties.

Usability an User Interface	AVG	N	STD	t-test Vs 4.5
Use of colours and sounds	5.068966	32	1.679265	1.916644848
System feedback	4.344828	29	2.229025	-0.3748854
System response to errors	4	29	2.35621	-1.1427600
System messages and reports	5.689655	29	2.625051	2.440519765
System clutter and UI “noise”	5.103448	29	1.963514	1.655027208
Total	4.841379	145	1.587591	2.58930188

Table 18 Usability an User Interface group results in Hail Hospital

Table 18 shows a strong satisfaction with system’s user interface. As previously mentioned, the hospital has good equipment and large screens with high accuracy so staff have no problems with the colors and sounds. Also, they have a flexible graphical user interface and easy handling of all categories of staff.

6.4 Discussion

After presenting the results of the SUS and QUIS models for both hospitals separately, we now compare the two hospitals by using a two-sample *t*-test. For the SUS model, the results of each question from both models is compared, while for the QUIS model, the sum of the total result was calculated and used for the comparison.

Comparison between Coombe and Hail Hospitals

System Usability Scales (SUS) Model

The graph (table 19) illustrates the difference between the SUS answers from the Hail and Coombe Hospitals, through the results’ collection and t-test. The critical value of the results is between 1.69 and -1.69. According to this graph, there are clear variations but also convergences between the responses of the staff of both hospitals. The two-sample t-test is computed by subtracting the Coombe data from the Hail data. Therefore a negative value suggests that the Hail’ staff had a higher score for the answer and viceversa.

It can be seen that the response *'I think that I would need the support of a technical person to be able to use this system'* comes at the top of the list with -4.74 for the Hail Hospital. Therefore Hail' staff find it difficult to deal with the system that prepares hospital training for them on the system. The second biggest number is for the question *I found the system unnecessarily complex* with 3.66 for the Coombe Hospital. Employees in this hospital do not have difficulty in dealing with the system so it does not require training courses. After that, the response '*I needed to learn a lot of things before I could get going with this system'* with 3.60 for Hail Hospital which is related to '*I think that I would need the support of a technical person to be able to use this system*'. These two reasons the hospital support team help staff from the beginning through to them becoming professional. Next, employees in the Coombe Hospital believe that there are contradictions in the terminology of an incomprehensible system so they answer (I found the system very cumbersome to use) with 2.25. The majority of Hail Hospital staff use the system so much that I think that I would like to use this system frequently came before the latest one with a score of -2.0. Finally, despite the fact that employees do not always use the system, 1.98 from the Coombe staff hospital gave the response: '*I found the system very cumbersome to use*'.

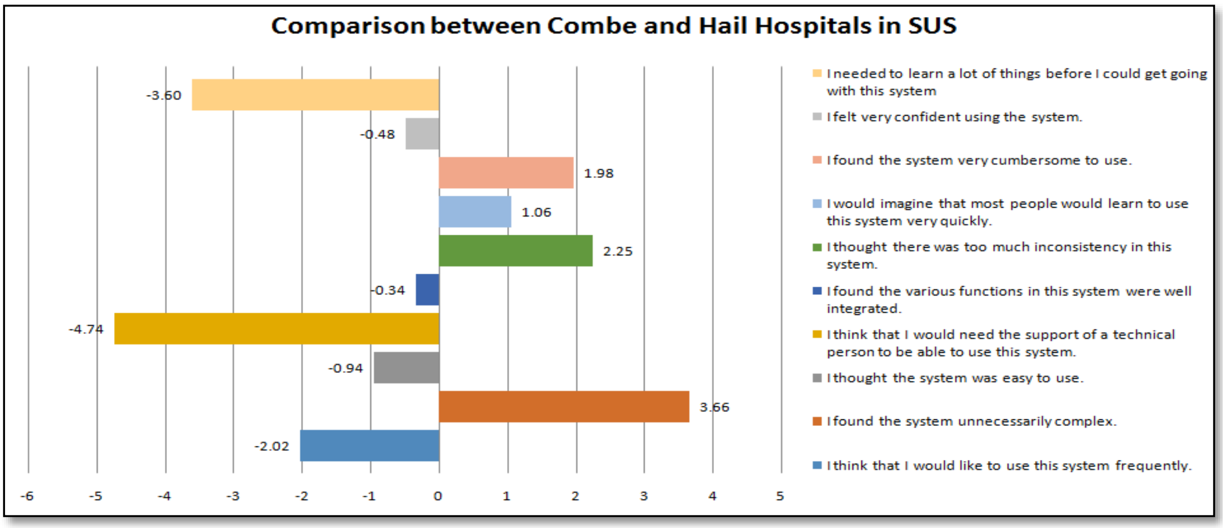

Table 19 Comparison between Combe and Hail Hospitals in SUS model

Questionnaire for User Interface Satisfaction (QUIS)

There is a marked difference between the results of the QUIS model in both hospitals. The results of each group in the Hail Hospital were collected and compared with the Coombe Hospital groups. In this case, the group results were compared in two different ways. First, there was a comparison based on the average results for each group. After collecting the average number of results for each group in each questionnaire, the group results were compared with each other.

Secondly there was a comparison on the basis of a t-test.

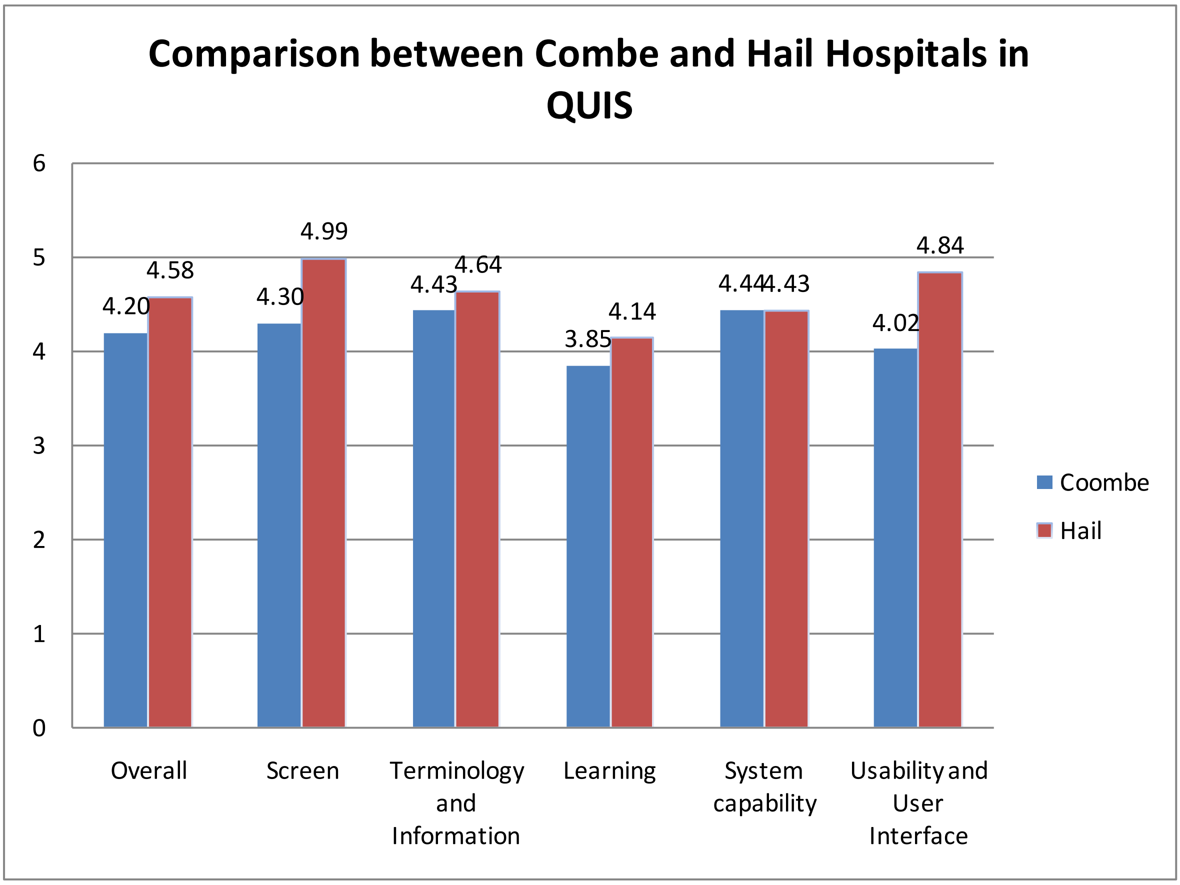

Table 20 Comparison between Combe and Hail Hospitals in QUIS

The midpoint of the rating scale (4.5) can be used as a criterion. If the item is above 5, it is perceived as being better than an arbitrary, mediocre value. However, that is generally not good enough. We may also use the overall mean of the group as a criterion. Such a mean is shown in the figure. (Lap.umd.edu, 2015)

In general, we considered the average answers from the Hail Hospital to be better than Coombe Hospital. In all the groups the Coombe did not exceed the criterion.

It can be clearly seen that the highest average is the screens group for the Hail Hospital was about five whereas the Coombe Hospital was just under 4.5. The second highest average is Usability and user Interface with just under 4.5 for the Hail Hospital. Terminology and information scored just above 4.5.

If we compare the results with a two-sample t-test, we obtained the situation depicted in Table 21. The critical value of the results is between 1.69 and -1.69. According to the graph, the Hail Hospital' staff has a higher opinion of the usability and user interface of LIS is than the Coombe Hospital' staff. Also, Hail' staff are overall much more satisfied about the system than their Irish counterparts..

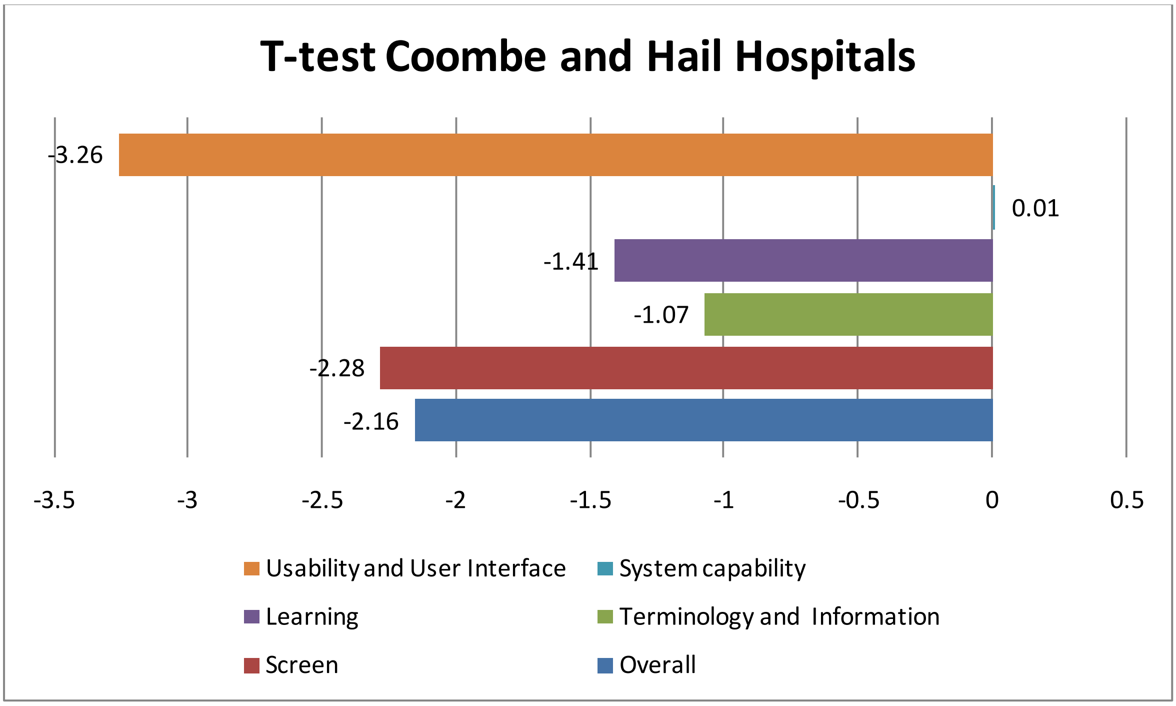

Table 21 Comparison by T-test between Coombe and Hail Hospitals

6.6 Interview Analysis

The interviews were done with employees who have experience with the LIS system and other lab systems as well. In the interview the subject of LIS usability was discussed.

Both staff in Coombe and Hail Hospitals agreed that they need help to learn the system for the first time but the staff training methods differ considerably. In the Hail Hospital the new employees take a training course for two weeks whereas the Coombe gives them only one day. Also, in the Hail hospital they do not need assistance from their colleagues. There is a technical team who are ready to help staff if they encounter difficulties with the system. In the Coombe hospital they ask their colleagues a lot as well as the IT manager in the hospital because they do not have a technical team.

When asked about the system in general and the ease of access to information in the Hail hospital they find the system to be relatively easy when they learn how to take advantage of all its properties. Also, they can easily access databases and share data with other hospitals. On the other hand, in the Coombe they find it difficult to learn the system and it takes time and effort. Also, they do not have access to databases and share files with other hospitals. This is because of the rules laid down by the hospital administration, which vary from one hospital to another and from one country to another.

Both employees agreed on two important things about content. First, basic functions such as showing results and printing reports were found to be simple and easy to understand and learn. Second, when they search for historical records, statistics and files about patients they find it difficult to understand the information they need to help. Not only that, these accumulated records contain a lot of information in a single page without search properties for certain information. This causes difficulty in reading for those who have weak vision.

Because the system uses a run rate system it does not contain graphics and backgrounds, so employees do not find it difficult to deal with the user interface and the system's colors. Also, they find navigating the system is smooth and easy.

Both sets of employees were asked to name their three least favourite aspects of the system. In the Hail hospital, the employees stated that there is a lot of pressure on the system because of the large number of requests so the system stops for a while and then returns to work. Also, LIS system request additional information about the patient in more than one place. When viewing the results the system will display a lot of information about the patient that they do not need. For the Coombe hospital, there was a call to change the user interface because it is boring, it has complex search properties and a lack of understanding of some of the displayed information on the system.

6.7 Conclusion

In this chapter, the results of the questionnaires and interviews for both hospitals were shown. These results include a t-test analysis, the average and number of participants through which one could see the differences between the results. For the SUS and the QUIS model, the t-test was used to find the difference between the answers and the neutral scores. Moreover, the answers to the SUS questionnaires were calculated for both hospitals and compared using a two-sample t-test. The total answers of each group in the QUIS questionnaires were also calculated in both hospitals and compared using a two-sample t-test. The results of the comparisons were validated and discussed in light of the feedback collected using face-to-face interviews. In QUIS model t-test shows that the Hail hospital staff is more satisfy than Coombe. The results of the SUS questionnaire were inconsistent without a clear trend.

In the next chapter, we will summarise the major findings and provide a set of recommendations to IT managers and laboratories that help to improve usability of the LIS system. These recommendations will be placed depending on the analysis of the experiment results.

7 CONCLUSIONS

7.1 Introduction

In this chapter, we present our conclusions as well as future works and recommendations for healthcare practitioners. Recommendations will be in three sections: general recommendations, Hospital Hail recommendations and Coombe Hospital recommendations. Limitations and future work will be described to give researchers an opportunity to improve and extend the present work.

7.2 Problem Definition & Research Overview

The LIS system today is one of the most superior systems operating in many laboratories and hospitals around the world. The system varies in composition and complexity across the different hospitals. This research is focused on the basic characteristics of the LIS system, in which all of the systems are involved, despite the different characteristics. This research aimed to investigate the effectiveness of the usability of the LIS system in two different hospitals. There is no doubt that the usability plays a vital role in the performance of staff in the laboratory. The QUIS and SUS have been chosen carefully after an analysis of the related studies in the area. The advantage of these models is that data privacy is not endangered since they focus only on aggregated data about LIS System Properties.

7.3 Contribution to the body of knowledge

This research examines two concepts that have not been investigated yet: the Questionnaire for User Interaction Satisfaction (QUIS) and System Usability Scale (SUS) in contexts of knowledge management in healthcare, taking into account the main six dimensions of usability (Effectiveness, Efficiency, Ease of use, System capability, learning, consistency, Screen, user Interface). In addition, the research have been done in two different hospitals in Ireland and Saudi Arabia with different Healthcare culture and work environment. This will allow both hospitals to get benefits from each other.

The results of this study will assist the Coombe and Hail hospitals to improve their LIS systems used to manage patients information by giving recommendations. Since each hospital have their own way to use the system, the results of this study give them opportunity to share their ways of using the system in order to mutually improve their work practices.

7.4 Results, Discussion & Recommendations

The data collected using the QUIS and SUS questionnaire were analyzed using both one sample t-test and two samples t-test. The objective was to gain accurate insights into the usability of the LIS system. Also, to compile more accurate information, the research was carried out on the LIS system in an Irish hospital and in a Saudi hospital .The results from both hospitals were collected, analysed and compared with each other. The aim of the comparison is not limited to finding the strengths and weaknesses of each hospital, but also to underline where each hospital can take advantage from the other hospitals experience. These results and comparisons give IT department in both hospitals information about the points that hinder the performance of the staff. Based on the results and analysis, general recommendations are now suggested, followed by personalized advice for the Hail Hospital and for the Coombe Hospital.

7.4.1 General Recommendations

These recommendations highlight the common problems in the system in both hospitals. In general staff members had a positive opinion of the system and believed that the system improved their performance and got rid of paper transactions. The following is a list of recommendations for both hospitals:

- Search Properties: staff suffers from search services in the system. There is plenty of incomprehensible information in the reports and results so it takes time to search.

- Small characters and figures in reports: employees and people who are visually impaired find it difficult to access information. They are sometimes forced to print reports and search for certain results.

- Navigating: staff find it difficult to gain access to new properties in the system. There is insufficient information and explanations about the properties in the system so their colleagues are giving help.

- Terminology and information: staff find it difficult to understand some of the performance information tasks.

7.4.2 Recommendations for the Coombe Hospital

In this section we provide recommendations specifically to the Coombe Hospital. These have been collected through the results' analysis of the questionnaire and interview. These recommendations are based on the feedback collected from the Hail Hospital experience and they could be useful for the Coombe Hospital.

- Learning: new staff take one day to train on the system which is not enough time and this has caused trouble for new employees. When they need help they ask their colleagues who may be busy and if they have a majer problem or suggestions they go to the IT manager. Sometimes they feel embarrassed by asking repeated questions of their colleagues. Also, there is no support team that assists staff and repair system errors. If there is no official learning period for new employees, it may cause disruption in staff work while they are assisting new employees. Simple mistakes may cause problems in the system so a training course is crucial here.

- Accessing information: staff find it difficult to reach some patient information and databases. They need permission to access this and it takes time with inquiries and producing results.

- Interface: Laboratory uses simple user interface and it is inflexible. This type of interface is not conducive to the discovery of the System Properties and it is problematic for its users.

- Feedback: Laboratory staff finds have difficulty in understanding why some tasks are carried out by the system. Even when LIS displays the results staff do not understand why some information is created. There are no an additional explanations for some tasks.

7.4.3 Recommendations for Hail Hospital

In this section, some recommendations are provided specifically to the Hail Hospital. These recommendations have been collected through the results analysis of the questionnaire and interview. These recommendations are based on feedback and the experience of the Coombe Hospital' staff and they could prove useful for Hail Hospital as well.

- Hard to read information: when showing the results and reports, all information and the numbers are in small sizes as well as they cannot control the size of the information. As mentioned in the general recommendations, LIS does not support good search properties. Older employees sometimes have to print paper to search. It would be better for the employees if the system allows them to control characters sizes.
- System speed: there are many operations on the system. At peak times the system is often slow and there is pressure on databases. This creates increased pressure in an already slow process ensuring delays in the delivery of results.

- Additional information: with inquiries or receiving results, the system asks to duplicate information which has already been inputted. The system should reduce the requirements of receipts, also the collection of results and samples.

7.5 Research Limitation

The experiment was designed and applied to measure the usability of the LIS system in two hospitals. Both systems are working in laboratories department, which are tied to several departments in the hospital. The questionnaire was distributed to the staff of both hospitals and they were given a week to complete the questionnaire. The number of employees was thirty-five for each hospital. Following that, one employee from each hospital was interviewed to discover more information about the usability of the system.

Limitations of the research were:

- The experiment was on one type of system in laboratories (LIS), while there are a lot of systems with different functions.

- The LIS system size varies depending on the capacity of the hospital, some hospitals have expensive equipment that could affect the perceived usability of the system

- Two models have been used to measure the usability. Even if these are well known and used models, they have limitations that could have been overcome by using more than two models.

- There were sixty-one out of seventy participants taking part in this experiment. Ideally, the more people involved, the higher accuracy and meaningfulness the result will yield. However this experiment was the largest scale that I could handle.

- The interviews were conducted with two employees, one from each hospital. These staff had an expertise of only three to five years within the system. It could have been better to increase the number of face-to-face interviews, but due to time limitation the number was limited to two individuals.

7.6 Future Works

There is potential to continue research in this area. The experiment could be expanded to include a more extensive quantitative and qualitative research. Other models can be used to measure the usability such as the eight golden rules. It would be very interesting, for example, to use a combination of models to measure the usability on the LIS system, assisting in covering parts that were not covered by the SUS and QUIS model. Also, this would give an opportunity to developers to see the limitations of the system. This research has been done in two different hospitals. Future research can be done in more than two hospitals as well as on more employees, and testing other types of KM systems for healthcare rather than for LIS.

7.7 Conclusion

In this chapter we have described our conclusions and provided a set of recommendations for both hospitals. These recommendations summarize the research results which will help to develop the system and improve the performance of staff. We also provided a list of research limitations and the potential for future work that can be used by LIS developers and practitioners to design and achieve a more efficient system.

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APPENDIX A

Surveys

Coombe Hospital

An Evaluation of the Usability of the Laboratory Information System (LIS) in the Coombe Women & Infants' University Hospital

Page 1

This questionnaire aims to measure System Usability Scale and User Interface Satisfaction with the LIS system. If you are working on the system I would be very grateful if you could answer these questions. Your participation will help me to finish my Master's dissertation which contains an investigation of the user Satisfaction and usability Scale of the LIS system at Dublin Institute of Technology. In addition, it will help me to identify the gaps in this system. No personal information will be collected. The questionnaire will only take about 4-5 minutes to complete.

Type of user:

- ○ Doctor
- ○ Nurse
- ○ Trainee
- ○ Employee

Gender:

- ○ Male
- ○ Female

Age:

- ○ 18-24
- ○ 24-30
- ○ 31-39
- ○ 40 years or more

How long have you been using the LIS system?

- ○ Never used it
- ○ Four years
- ○ Three years
- ○ Two years
- ○ One year
- ○ Less than one year

How long have you been working in the hospital?

- ○ Never
- ○ Four years
- ○ Three years
- ○ Two years
- ○ One year
- ○ Less than one year

The System Usability Scale (SUS)

	Strongly Disagree 1	Disagree 2	Neural 3	Agree 4	Strongly Agree 5
I think that I would like to use this system frequently.	○	○	○	○	○
I found the system unnecessarily complex.	○	○	○	○	○
I thought the system was easy to use.	○	○	○	○	○
I think that I would need the support of a technical person to be able to use this system.	○	○	○	○	○
I found the various functions in this system were well integrated.	○	○	○	○	○
I thought there was too much inconsistency in this system.	○	○	○	○	○
I would imagine that most people would learn to use this system very quickly.	○	○	○	○	○
I found the system very cumbersome to use.	○	○	○	○	○
I felt very confident using the system.	○	○	○	○	○
I needed to learn a lot of things before I could get going with this system	○	○	○	○	○

The Questionnaire for User Interaction Satisfaction (QUIS)

Overall reaction to LIS system

	0	1	2	3	4	5	6	7	8	9	
Terrible	○	○	○	○	○	○	○	○	○	○	Wonderful
Difficult	○	○	○	○	○	○	○	○	○	○	Easy
Frustrating	○	○	○	○	○	○	○	○	○	○	Satisfying
Inadequate power	○	○	○	○	○	○	○	○	○	○	Adequate power
Dull	○	○	○	○	○	○	○	○	○	○	Stimulating
Rigid	○	○	○	○	○	○	○	○	○	○	Flexible

Screen

Characters on the computer screen are:

	0	1	2	3	4	5	6	7	8	9	
Hard to read	○	○	○	○	○	○	○	○	○	○	Easy to read

Highlighting on the screen simplifies task:

	0	1	2	3	4	5	6	7	8	9	
Not at all	○	○	○	○	○	○	○	○	○	○	Very much

Organization of information on screen is:

	0	1	2	3	4	5	6	7	8	9	
Confusing	○	○	○	○	○	○	○	○	○	○	Very clear

Sequence of screens is:

	0	1	2	3	4	5	6	7	8	9	
Confusing	O	O	O	O	O	O	O	O	O	O	Very clear

Terminology and LIS information

Use of terms throughout system is:

	0	1	2	3	4	5	6	7	8	9	
Inconsistent	O	O	O	O	O	O	O	O	O	O	Consistent

Computer terminology is related to the task you are doing:

	0	1	2	3	4	5	6	7	8	9	
Never	O	O	O	O	O	O	O	O	O	O	Always

Position of messages on screen is:

	0	1	2	3	4	5	6	7	8	9	
Inconsistent	O	O	O	O	O	O	O	O	O	O	Consistent

Messages on screen which prompt user for input are:

	0	1	2	3	4	5	6	7	8	9	
Confusing	O	O	O	O	O	O	O	O	O	O	Clear

Computer keeps you informed of its actions:

	0	1	2	3	4	5	6	7	8	9	
Never	O	O	O	O	O	O	O	O	O	O	Always

Error messages are:

	0	1	2	3	4	5	6	7	8	9	
Unhelpful	O	O	O	O	O	O	O	O	O	O	Helpful

Learning

Learning to operate the system is:

	0	1	2	3	4	5	6	7	8	9	
Difficult	O	O	O	O	O	O	O	O	O	O	Easy

Exploring new features by trial and error:

	0	1	2	3	4	5	6	7	8	9	
Difficult	O	O	O	O	O	O	O	O	O	O	Easy

Remembering names and using commands is:

	0	1	2	3	4	5	6	7	8	9	
Difficult	O	O	O	O	O	O	O	O	O	O	Easy

Tasks can be performed in a straightforward manner:

	0	1	2	3	4	5	6	7	8	9	
Never	O	O	O	O	O	O	O	O	O	O	Always

Help messages on the screen are;

	0	1	2	3	4	5	6	7	8	9	
Unhelpful	○	○	○	○	○	○	○	○	○	○	Helpful

Supplemental reference materials are:

	0	1	2	3	4	5	6	7	8	9	
Confusing	○	○	○	○	○	○	○	○	○	○	Clear

System capability

System speed is:

	0	1	2	3	4	5	6	7	8	9	
Too slow	○	○	○	○	○	○	○	○	○	○	Fast enough

System reliability:

	0	1	2	3	4	5	6	7	8	9	
Unreliable	○	○	○	○	○	○	○	○	○	○	Reliable

System tends to be:

	0	1	2	3	4	5	6	7	8	9	
Noisy	○	○	○	○	○	○	○	○	○	○	Quiet

Correcting your mistakes is:

	0	1	2	3	4	5	6	7	8	9	
Difficult	○	○	○	○	○	○	○	○	○	○	Easy

Experienced and inexperienced users' needs are taken into consideration:

	0	1	2	3	4	5	6	7	8	9	
Never	○	○	○	○	○	○	○	○	○	○	Always

Usability and User Interface

Use of colours and sounds:

	0	1	2	3	4	5	6	7	8	9	
Poor	○	○	○	○	○	○	○	○	○	○	Good

System feedback:

	0	1	2	3	4	5	6	7	8	9	
Poor	○	○	○	○	○	○	○	○	○	○	Good

System's response to errors is:

	0	1	2	3	4	5	6	7	8	9	
Awkward	○	○	○	○	○	○	○	○	○	○	Non-problematic

System's messages and reports are:

	0	1	2	3	4	5	6	7	8	9	
Poor	○	○	○	○	○	○	○	○	○	○	Good

System's clutter and Use Interface "noise" is:

	0	1	2	3	4	5	6	7	8	9	
Poor	○	○	○	○	○	○	○	○	○	○	Good

Hail Hospital

Laboratory Information System (LIS) في مختبرات مستشفى حائل العام
تقييم فعالية قابلية استخدام نظام

Page 1

السلام عليكم ,, يهدف هذا الاستبيان الى قياس قابلية استخدام ورضى المستخدم عن واجة المستخدم الرسوميه في Laboratory Information System (LIS)
اذا كنت تعمل في مختبرات مستشفى حائل العام او سبق وان عملت ارجوا التفضل ومساعدتي في الاجابه على الاستبيان. مشاركتك في الاجابه ستساعدني في انهاء
بحث الماجستير وتحديد ثغرات النظام. لا يطلب منك الاستبيان اي معلومات شخصيه وقد يستغرق 4-5 دقائق
شكرا

نوع المستخدم

- ○ دكتور
- ○ ممرض
- ○ متدرب
- ○ موظف

الجنس

- ○ ذكر
- ○ انثى

العمر

- ○ 18-24
- ○ 24-30
- ○ 31-39
- ○ فوق 40

ماهي خبرتك في التعامل مع نظام LIS

- ○ لم استخدمه ابدا
- ○ اكثر من اربع سنوات
- ○ ثلاث سنوات
- ○ سنتين
- ○ سنه
- ○ اقل من سنه

ماهي المده التي عملت بها في مستشفى حائل العام

- ○ لا اعمل في المستشفى
- ○ اكثر من اربع سنوات
- ○ ثلاث سنوات
- ○ سنتين
- ○ سنه
- ○ اقل من سنه

قياس قابلية الاستخدام

	غير موافق بشده	غير موافق	محايد	موافق	موافق بشده
اعتقد انني استخدم النظام كثيرا	○	○	○	○	○
اجد النظام معقد اكثر من اللازم	○	○	○	○	○
اعتقد ان النظام سهل الاستخدام	○	○	○	○	○
احتاج الى دعم تقني قبل استخدام النظام	○	○	○	○	○
ادوات وخيارات النظام مندمجه مع بعضها البعض	○	○	○	○	○
اعتقد هناك الكثير من التناقضات في النظام	○	○	○	○	○
تعلم استخدام النظام سهل وسريع	○	○	○	○	○
النظام مرهق في الاستخدام	○	○	○	○	○
اشعر بثقه كبيره في استخدام النظام	○	○	○	○	○
تعلمت الكثير قبل اكون خبير في النظام	○	○	○	○	○

قياس مستوى رضى المستخدم عن الواجهه الرسوميه
ارجوا تقييم الاجابه من 0- الى 9

الانطباع بشكل عام حول النظام

	0	1	2	3	4	5	6	7	8	9	
غير جيد على الاطلاق	○	○	○	○	○	○	○	○	○	○	رهيب
صعب	○	○	○	○	○	○	○	○	○	○	سهل
محبط	○	○	○	○	○	○	○	○	○	○	مرضي
غير ملائم	○	○	○	○	○	○	○	○	○	○	ملائم
ممل	○	○	○	○	○	○	○	○	○	○	محفز
غير مرن	○	○	○	○	○	○	○	○	○	○	مرن

الشاشه
الحروف على شاشه الكمبيوتر

	0	1	2	3	4	5	6	7	8	9	
صعبة القراءه	○	○	○	○	○	○	○	○	○	○	سهلة القراء

سهولة تحديد الطلبات على الشاشه

	0	1	2	3	4	5	6	7	8	9	
غير سهله	○	○	○	○	○	○	○	○	○	○	جدا سهله

التعرف على المعلومات على الشاشه

	0	1	2	3	4	5	6	7	8	9	
مشتت	○	○	○	○	○	○	○	○	○	○	واضح

تنظيم المعلومات على الشاشه

	0	1	2	3	4	5	6	7	8	9	
مشتت	○	○	○	○	○	○	○	○	○	○	واضح

مسطلحات وعناوين نظام LIS

استخدام المسطلحات في جميع خصائص النظام

	0	1	2	3	4	5	6	7	8	9	
غير متناسق	○	○	○	○	○	○	○	○	○	○	متناسق

المسطلحات دائما مرتبطه بالمهام التي تقومون بها- مثال - كل عينه لها مسطلح متوافق معها

	0	1	2	3	4	5	6	7	8	9	
غير متطابقه	○	○	○	○	○	○	○	○	○	○	دائما متطابقه

الرسائل على الشاشه

	0	1	2	3	4	5	6	7	8	9	
غير متناسق	○	○	○	○	○	○	○	○	○	○	متناسق

الرسائل التي توجه المستخدم عند ادخال معلومات للنظام

	0	1	2	3	4	5	6	7	8	9	
مشتته	○	○	○	○	○	○	○	○	○	○	واضحه

يبقيك الكمبيوتر على اطلاع على المهمات اثناء آدائها من البدايه للنهايه

	0	1	2	3	4	5	6	7	8	9	
غير مطلع	○	○	○	○	○	○	○	○	○	○	دائما

رسائل الخطأ

	0	1	2	3	4	5	6	7	8	9	
مفيده	○	○	○	○	○	○	○	○	○	○	غير مفيده

سهولة التعلم
تعلم تشغيل النظام

	0	1	2	3	4	5	6	7	8	9	
صعبه	○	○	○	○	○	○	○	○	○	○	سهله

اكتشاف خصائص جديده في النظام من خلال المحاوله

	0	1	2	3	4	5	6	7	8	9	
صعبه	○	○	○	○	○	○	○	○	○	○	سهله

سهولة خاصية البحث في النظام

	0	1	2	3	4	5	6	7	8	9	
صعبه	○	○	○	○	○	○	○	○	○	○	سهله

تؤدى المهام بطريقة مباشره في النظام

	0	1	2	3	4	5	6	7	8	9	
غير مباشره	○	○	○	○	○	○	○	○	○	○	دائما مباشره

الرسائل المساعده على الشاشه

	0	1	2	3	4	5	6	7	8	9	
مفيده	○	○	○	○	○	○	○	○	○	○	غير مفيده

يعطي النظام مراجع ومعلومات اكثر حول الخصائص اذا احتاج المستخدم

	0	1	2	3	4	5	6	7	8	9	
مراجع مشتته	○	○	○	○	○	○	○	○	○	○	مراجع واضحه

قدرة النظام

سرعة النظام

	0	1	2	3	4	5	6	7	8	9	
جدا بطئ	○	○	○	○	○	○	○	○	○	○	سرعه كافيه

موثوقية النظام

	0	1	2	3	4	5	6	7	8	9	
غير موثوق	○	○	○	○	○	○	○	○	○	○	موثوق

النظام يميل إلى أن يكون

	0	1	2	3	4	5	6	7	8	9	
مزعج	○	○	○	○	○	○	○	○	○	○	غير مزعج

تصحيح الاخطاء

	0	1	2	3	4	5	6	7	8	9	
صعب	○	○	○	○	○	○	○	○	○	○	سهل

يميز النظام بين المستخدم الخبير وغير الخبير

	0	1	2	3	4	5	6	7	8	9	
لا يميز	○	○	○	○	○	○	○	○	○	○	يميز

واجهة المستخدم

الوان واصوات الشاشه

	0	1	2	3	4	5	6	7	8	9	
رديئه	○	○	○	○	○	○	○	○	○	○	جيده

التغذيه الرجعه

	0	1	2	3	4	5	6	7	8	9	
رديئه	○	○	○	○	○	○	○	○	○	○	جيده

استجابه النظام للأخطاء

	0	1	2	3	4	5	6	7	8	9	
غير ملائم	○	○	○	○	○	○	○	○	○	○	ملائم

تقارير النظام

	0	1	2	3	4	5	6	7	8	9	
رديئه	○	○	○	○	○	○	○	○	○	○	جيده

واجهة المستخدم بشكل عام

	0	1	2	3	4	5	6	7	8	9	
رديئه	○	○	○	○	○	○	○	○	○	○	جيده

Surveys results

Coombe SUS model

The System Usability Scale (SUS)					is the score of the answer different from the neutral score (=0)?				
	Strongly Disagree	Disagree	Neural	Agree	Strongly Agree	Score	N	STD	T-test with 0 (inside the group)
I think that I would like to use this system frequently.	2	4	18	7	1	0.03125	32	0.82824	0.213437706
I found the system unnecessarily complex.	0	8	6	14	4	0.4375	32	0.72298	3.423140201
I thought the system was easy to use.	1	10	6	12	1	0.06667	30	0.94234	0.387492129
I think that I would need the support of a technical person to be able to use this system.	1	9	10	11	1	0.0625	32	0.8854	0.399314267
I found the various functions in this system were well integrated.	0	15	7	8	2	-0.09375	32	1.06481	
I thought there was too much inconsistency in this system.	1	7	11	12	1	0.15625	32	0.79697	1.109053867
I would imagine that most people would learn to use this system very quickly.	0	10	9	12	1	0.125	32	0.79764	0.886498021
I found the system very cumbersome to use.	2	7	9	11	3	0.1875	32	0.94055	1.127696162
I felt very confident using the system.	1	6	13	10	2	0.1875	32	0.79879	1.327837663
I needed to learn a lot of things before I could get going with this system	0	8	13	9	2	0.15625	32	0.76855	1.15006767
TOTAL	8	84	102	106	18	0.13208	318	0.85753	

Hail SUS model

The System Usability Scale (SUS)					is the score of the answer different from the neutral score (=0)?				
	Strongly Disagree	Disagree	Neural	Agree	Strongly Agree	Score	N	STD	T-test with 0 (inside the group)
I think that I would like to use this system frequently.	0	6	9	11	2	0.32143	28	0.69341	2.452852437
I found the system unnecessarily complex.	1	9	13	5	1	-0.13793	29	0.96971	-0.765981155
I thought the system was easy to use.	0	7	9	9	2	0.22222	27	0.7698	1.5
I think that I would need the support of a technical person to be able to use this system.	0	5	6	5	11	0.81481	27	0.76483	5.535710023
I found the various functions in this system were well integrated.	0	9	13	6	1	-0.03448	29	0.83442	-0.222544244
I thought there was too much inconsistency in this system.	5	8	7	7	1	-0.32143	28	1.44577	-1.176427513
I would imagine that most people would learn to use this system very quickly.	2	9	7	7	2	-0.07407	27	1.14932	-0.334893783
I found the system very cumbersome to use.	4	6	14	4	2	-0.2	30	1.20333	-0.910345694
I felt very confident using the system.	0	7	8	10	2	0.25926	27	0.75494	1.784448779
I needed to learn a lot of things before I could get going with this system	1	4	8	6	10	0.68966	29	0.82734	4.488981225
TOTAL	13	70	94	70	34	0.14947	281	0.96602	

Coombe QUIS model

The Questionnaire for User Interaction Satisfaction (QUIS) Overall reaction to LIS system

is the score of the answer different from the neutral score (4.5)?

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.
	terrible	1	2	2	6	10	7	2	2	1	0	wonderful	4.0303	32	1.7408	1.526334
	difficult	0	2	4	3	12	4	5	0	1	1	easy	4.1875	32	3.9911	0.442931
	frustrating	1	1	5	6	8	6	3	2	0	0	satisfying	3.8438	32	4.2883	0.86568
	inadequate power	0	2	2	2	15	5	4	2	0	0	adequate power	4.2188	32	2.9283	0.543307
	dull	1	2	0	3	13	7	2	3	1	0	stimulating	4.3438	32	6.9847	0.126546
	rigid	0	3	2	2	8	6	6	5	0	0	flexible	4.5625	32	4.7533	-0.07438
	TOTAL	3	12	15	22	66	35	22	14	3	1		4.1969	193	2.7414	1.536075

Screen

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.
Characters on the computer screen	hard to read	0	2	0	1	14	8	2	3	1	1	easy to read	4.7188	32	1.4592	-0.848
Highlighting on the screen simplifies task	not at all	1	2	1	5	9	9	4	1	0	0	very much	4.0938	32	5.9409	0.386828
Organization of information on screen	confusing	0	2	2	4	10	9	4	1	0	0	very clear	4.1875	32	3.8846	0.455075
Sequence of screens	confusing	0	2	1	6	10	8	4	0	1	0	very clear	4.1875	32	4.166	0.424333
	TOTAL	1	8	4	16	43	34	14	5	2	1		4.2969	128	4.08	0.563265

Terminology and LIS information Use of terms throughout system is:

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.
Use of terms throughout system	inconsistent	0	2	1	5	10	6	5	2	1	0	consistent	4.4063	32	1.598	0.331864
Computer terminology is related to the task you are doing	never	0	0	2	3	10	9	4	4	0	0	always	4.6875	32	3.3284	-0.31867
Position of messages on screen	inconsistent	0	0	3	7	7	7	4	4	0	0	consistent	4.4375	32	3.5184	0.100488
Messages on screen which prompt user for input	confusing	0	0	3	5	11	5	4	2	1	1	clear	4.5313	32	2.2168	-0.07975
Computer keeps you informed of its actions	never	0	2	3	3	4	11	4	2	1	0	always	4.4667	30	2.8643	0.06374
Error messages	unhelpful	1	1	6	3	7	9	2	2	1	0	helpful	4.0313	32	3.891	0.681488
	TOTAL	1	5	18	26	49	47	23	16	4	1		4.4263	190	3.0368	0.334454

Learning

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.
Learning to operate the system	difficult	0	3	6	4	7	9	2	1	0	0	easy	3.7188	32	1.5659	2.822225
Exploring new features by trial and error	difficult	0	3	2	8	9	4	4	1	1	0	easy	3.9375	32	2.7229	1.168609
Remembering names and use of commands	difficult	1	1	5	5	8	8	1	3	0	0	easy	3.9063	32	3.3121	1.0141
Tasks can be performed in a straightforward manner	never	1	1	4	5	8	8	2	1	1	0	always	3.9677	31	3.2211	0.920016
Help messages on the screen	unhelpful	0	4	4	5	8	7	4	0	0	0	helpful	3.6875	32	3.2028	1.435063
Supplemental reference materials	confusing	0	4	4	3	10	7	1	2	1	0	clear	3.875	32	2.9974	1.179536
	TOTAL	2	16	25	30	50	43	14	8	3	0		3.8482	191	3.6444	2.471878

System capability

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.
System speed	too slow	0	0	5	2	7	8	6	4	0	0	fast enough	4.625	32	1.5562	-0.45437
System reliability	unreliable	1	1	1	5	7	9	5	2	1	0	reliable	4.4688	32	2.8499	0.062029
System tends to be	noisy	0	0	2	2	11	7	4	3	1	2	quiet	5	32	2.6868	-1.05272
Correcting your mistakes	difficult	2	0	6	5	4	8	4	3	0	0	easy	4	32	3.293	0.858925
Experienced and inexperienced users' needs are taken into consideration	never	2	0	3	5	9	7	4	1	1	0	always	4.0938	32	2.1553	1.066232
	TOTAL	5	1	17	19	38	39	23	13	3	2		4.4375	160	2.8844	0.274089

Usability an User Interface

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.
Use of colours and sounds	poor	3	1	10	3	2	5	7	6	0	0	good	3.973	32	2.4172	1.23337
System feedback	poor	3	2	12	3	2	8	1	1	0	0	good	3	32	4.5242	1.875515
System response to errors	awkward	2	2	2	10	5	4	5	3	1	0	gracious	3.9706	34	3.0618	1.008225
System messages and reports	poor	0	0	5	6	7	8	3	3	0	0	good	4.2188	32	2.7162	0.585734
System clutter and UI "noise"	poor	0	0	1	2	8	12	3	4	1	0	good	4.9677	31	2.5227	-1.03232
	TOTAL	8	5	30	24	24	37	19	17	2	0		4.0181	166	4.4968	1.380818

Hail QUIS model

The Questionnaire for User Interaction Satisfaction (QUIS) Overall reaction to LIS system		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.5
	terrible	1	0	3	3	8	6	1	3	3	0	wonderful	4.5714	32	1.8274	-0.221116
	difficult	0	3	3	4	5	6	1	2	2	3	easy	4.6207	29	2.4535	-0.264902
	frustrating	3	2	2	4	6	3	4	4	0	1	satisfying	4.069	29	2.0798	1.1160558
	inadequate power	1	2	3	0	3	7	8	4	0	1	adequate power	4.8276	29	1.6509	-1.068568
	dull	1	0	5	1	8	6	6	1	0	1	stimulating	4.3793	29	2.4589	0.2643193
	rigid	0	3	1	3	4	5	4	7	1	1	flexible	5	29	3.243	-0.830268
	TOTAL	6	10	17	15	34	33	24	21	6	7		4.578	173	1.9097	-0.53747

Screen

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.5
Characters on the computer screen	hard to read	0	0	5	6	3	4	0	6	4	2	easy to read	5.0667	32	2.0381	-1.572806
Highlighting on the screen simplifies task	not at all	0	1	1	4	5	3	2	5	6	2	very much	5.6207	29	2.3077	-2.615222
Organization of information on screen	confusing	0	0	3	4	0	8	3	6	3	1	very clear	5.3929	28	2.2993	-2.054819
Sequence of screens	confusing	0	3	6	6	4	4	1	1	1	2	very clear	3.8571	28	2.5592	1.3291908
	TOTAL	0	4	15	20	12	19	6	18	14	7		4.9913	115	2.4447	-2.155147

Terminology and LIS information Use of terms throughout system is:

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.5
Use of terms throughout system	inconsistent	0	2	6	1	4	4	5	4	2	1	consistent	4.6897	32	1.9971	-0.537207
Computer terminology is related to the task you are doing	never	0	1	6	2	7	6	3	1	1	2	always	4.4138	29	1.3581	0.3418405
Position of messages on screen	inconsistent	0	1	6	5	4	3	2	6	1	1	consistent	4.4828	29	2.4797	0.0374431
Messages on screen which prompt user for input	confusing	0	4	2	4	7	3	3	2	3	1	clear	4.4138	29	2.0145	0.2304457
Computer keeps you informed of its actions	never	0	0	4	7	3	5	2	4	3	1	always	4.7931	29	1.979	-0.797576
Error messages	unhelpful	1	1	2	3	6	2	4	7	2	1	helpful	5.0345	29	2.2117	-1.301369
	TOTAL	1	9	26	22	31	23	19	24	12	7		4.6379	174	2.1642	-0.840685

Learning

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.5
Learning to operate the system	difficult	1	2	7	4	2	6	3	2	1	1	easy	3.9655	32	1.9172	1.5770447
Exploring new features by trial and error	difficult	2	2	6	6	3	5	3	1	0	1	easy	3.5517	29	2.1246	2.4035808
Remembering names and use of commands	difficult	1	1	4	7	5	2	3	3	1	2	easy	4.3103	29	1.9318	0.5286967
Tasks can be performed in a straightforward manner	never	0	1	2	6	8	2	3	4	1	2	always	4.7241	29	1.8206	-0.662977
Help messages on the screen	unhelpful	0	1	4	5	5	3	4	2	4	1	helpful	4.7586	29	2.6108	-0.533452
Supplemental reference materials	confusing	8	2	4	3	5	0	5	3	3	1	clear	3.6176	34	2.0529	2.5061425
	TOTAL	12	9	27	31	28	18	21	15	10	8		4.1397	179	1.888	2.553534

System capability

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.5
System speed	too slow	0	0	1	6	5	6	5	5	1	0	fast enough	4.931	32	1.4986	-1.627092
System reliability	unreliable	0	0	3	4	4	5	5	0	2	6	reliable	5.4828	29	1.9026	-2.781567
System tends to be	noisy	0	0	2	5	4	8	2	4	3	1	quiet	5.1034	29	2.2968	-1.414841
Correcting your mistakes	difficult	0	2	4	4	5	8	4	1	0	1	easy	4.2069	29	2.5746	0.6130627
Experienced and inexperienced users' needs are taken into consideration	never	13	1	3	2	2	5	0	1	0	2	always	2.4483	29	2.9907	3.6943611
	TOTAL	13	3	13	21	20	32	16	11	6	10		4.4345	145	3.554	0.2219816

Usability an User Interface

		0	1	2	3	4	5	6	7	8	9		AVG	N	STD	T-test vs 4.5
Use of colours and sounds	poor	1	1	2	5	6	5	1	0	0	8	good	5.069	32	1.6793	-1.916645
System feedback	poor	0	1	3	7	6	6	0	5	0	1	good	4.3448	29	2.229	0.3748855
System response to errors	awkward	1	3	8	2	2	4	3	4	1	1	gracious	4	29	2.3562	1.1427601
System messages and reports	poor	0	0	3	3	4	5	3	3	2	6	good	5.6897	29	2.6251	-2.44052
System clutter and UI “noise”	poor	0	0	4	5	5	4	1	3	5	2	good	5.1034	29	1.9635	-1.655027
	TOTAL	2	5	20	22	23	24	8	15	8	18		4.8414	145	1.5876	-2.589302

T-test SUS

Comparison between Combe and Hail							
	T-test (Coombe-Hail)	negative = combe > hail, negative combe < hail					
I think that I would like to use this system frequently.	-2.018180251						
I found the system unnecessarily complex.	3.661367889						
I thought the system was easy to use.	-0.944188418					Critical V:	Critical Values2
I think that I would need the support of a technical person to be able to use this system.	-4.737677305				Maximum	1.69	1.69
I found the various functions in this system were well integrated.	-0.336098256				Minimum	-1.69	-1.69
I thought there was too much inconsistency in this system.	2.254064149						
I would imagine that most people would learn to use this system very quickly.	1.062598968						
I found the system very cumbersome to use.	1.979981446						
I felt very confident using the system.	-0.479971157						
I needed to learn a lot of things before I could get going with this system	-3.599846064						
TOTAL	-0.319729965						

T-test QUIS

AREA	Coombe	Hail	T-test Coombe-Hail	negative = combe > hail, negative combe < hail
Overall	4.196891	4.578035	-2.15572787	
Screen	4.296875	4.991304	-2.282708435	
Terminology and Information	4.426316	4.637931	-1.073403029	
Learning	3.848168	4.139665	-1.409877098	
System capability	4.4375	4.434483	0.011286169	
Usability and User Interface	4.018072	4.841379	-3.258830742	

APPENDIX B

Interview questions

Warm up

How are you ?
How long have you been working in the hospital ?
How long have you worked on LIS system ?

Main Interview

When you use LIS system the first time did you need a technical person to help you?
How are you finding the system? WHY?
Have you had any difficulties accessing the system?
How do you share information with others through the system?
Do you / Have you ask your colleague for any assistance?
What do you think the purpose of this system is?
Who do you think the intended audience is?
Did the content make sense and meet your expectations?
Was there something missing you were expecting to see?
How did you find the of the system?
Problems or kudos on the color scheme?
Was the text easy to read?
How intuitive and helpful is the navigation system?
What would encourage you to return to this system in the future?
Name your three favorite things about the system, and your three least favorite
If you could change one thing on the system, whether it is major or minor, w hat would be at the top of the to do list?

Cool down

Have you ever see yourself working on LIS company